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RECENT PROGRESS IN CODLING MOTH CONTROL IN BRITISH COLUMBIA[1]

I. KILLING THE MATURE LARVA

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INTRODUCTION

As the season of 1942 approaches, the question arises as to whether apple growing can survive much longer as an important industry in the Interior of British Columbia unless new means are speedily found for controlling the codling moth. Present methods are largely confined to attacking the insect in but one stage of its life cycle. "First brood" sprays of lead arsenate sometimes continue by themselves to be effective where infestation is light, but all too often in recent years have failed to prevent a gradual or even rapid increase in moth population. This does not necessarily imply a weakness in present methods of attacking the young larva, but may rather point to a failure to deal as effectively with other stages in the life history of the codling moth.

At the Dominion Entomological Laboratory, Vernon, attention has been directed to 2 periods in the life history, other than the egg or first instar larva, that afford opportunity for attack. The first period extends from the time the mature worm leaves the fruit until it emerges as a moth. The second is the period during which the moth is in flight. Both present comparatively unexplored fields for investigation. The urgency of the codling moth situation in British Columbia, as well as in other apple growing districts is sufficient reason for the presentation of a progress report on the Vernon investigations in hope of stimulating the interest of workers in other districts.

Methods of Killing the Mature Larva

As a means of killing mature larvae, scraping and banding was first recommended by Thatcher (5) in 1825 and later very much improved by the introduction of the chemically treated corrugated band of Siegler, Brown, Ackerman, and Newcomer (4). Scraping, however, has the effect of obliterating the most favoured cocooning sites on the trunk and main limbs of the tree, and thus encourages larvae to form cocoons in even less accessible places. This point has been mentioned by Headlee (3) in advocating the use of an emulsifiable steam distilled pine oil product "Dormex", to kill hibernating larvae. Since this substance was injurious to callus tissue, it was necessary to apply it carefully with a brush.

More recently, in the West the proprietary product "Pyrocide" has been reported by Gnadinger, Moore and Coulter (2) to be effective as a larvicide for dormant application. "Pyrocide" appears to be a solution

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[2] Insect Ranger.

of pyrethrins in an oil of the kerosene type. Ginsburg (1) contends that kerosene alone is a potent larvicide in the dormant season.

At the Vernon laboratory, some success has attended experiments with 3,5-dinitro-orthocresol as an insecticide against mature larvae. This compound hereafter referred to as dinitrocresol, kills both by contact and by ingestion, and moreover retains its lethal properties to a considerable degree for several months. The dinitrocresol used in these experiments had the following specifications: M.P. 81.5° to 83° C.; water solubility (25° C.) 0.01769 g./100 ml.; pH after 24 hours 3.4; ash, 0.81%.

EXPERIMENTAL PROCEDURE

In March, 1941, during the delayed dormant period, a field experiment was undertaken to determine the effect of a dormant treatment of an oil solution of dinitrocresol on codling moth infestation in a 5½-acre block of 30-year-old apple trees. The trees had never been scraped and the infestation the previous year was about 50%, despite the application of 4 lead arsenate cover sprays. The trunk and main limbs of the trees were treated to a height of 8 to 9 feet with dinitrocresol solution, applied by a power sprayer equipped with short spray rods and angle nozzles. Pressure was reduced to a minimum by unscrewing the release valve with the result that the liquid was expelled in a cone of fine droplets rather than a mist. Approximately 1 gallon of oil solution was applied to a tree capable of bearing 40 to 50 boxes of fruit. Two men treated the trees at a rate of approximately 50 per hour. One and one-half acres were not treated and served as a check. A 2-acre block adjoining the check area and with similar topography and carry-over of larvae, was treated with 2% dinitrocresol in diesel oil. One acre was treated with 1% dinitrocresol in stove oil and another acre with 1% dinitrocresol in kerosene. These represented dinitrocresol solutions fairly close to saturation.

Specifications of the oils were as follows: diesel oil, Vis. 44 S.S.U. at 100° F., U.R., 75%; stove oil, Vis. 32 S.S.U. at 100° F., U.R. 80%; kerosene, Vis. 32 S.S.U. at 100° F., U.R. 96%.

Cost of the diesel oil-dinitrocresol treatment was approximately 25 cents per tree or about 1 cent per box of fruit, labour included.

The entire block was sprayed with the summer larvicidal applications recommended for the district, 4 "first brood" sprays of lead arsenate-protein spreader, and 1 "second brood" spray of cryolite-protein spreader being applied.

After first generation attack and again at harvest, 26 trees were sampled for codling moth infestation. In the first generation records, 200 apples per tree were counted and in the harvest record, 500 apples per tree. Only the 2-acre diesel oil plot and the adjoining 1½-acre check plot were adequately sampled, but sufficient records were taken in the stove oil and kerosene plots to indicate that infestation was about midway between that in the diesel oil plot and that in the check plot.

RESULTS

Examination 3 weeks after treatment failed to reveal any living larvae or pupae on the treated portions of the trees although both were numerous on the check trees. At that time injury to the trees began to be evident.

It was much more pronounced in the plots treated with 1% dinitrocresol in stove oil or kerosene than in the plot treated with 2% dinitrocresol in diesel oil. At the end of the year several trees had died in the stove oil- and kerosene-treated blocks, but none had been fatally affected in the diesel oil block. Damage was chiefly confined to the cambium at ground level where the oil solution had concentrated and persisted. Apparently this injury was due at least in large measure to the oil solvent. As will be seen from Table 2, the crop was not reduced by the delayed dormant diesel oil-dinitrocresol treatment. It may be, however, that injury will become more apparent by the summer of 1942.

TABLE 1.—INFESTATION BY FIRST GENERATION LARVAE, JULY 22

Plot	Infestation	Per 100 fruits			
		Stings		Entries	
		McIntosh	Jonathan	McIntosh	Jonathan
Diesel oil-dinitrocresol plot	Range of infestation	7 – 13.5	5 – 7	0.5 – 1.5	0 – 0.5
	Average infestation	10	5.9	1	0.1
Check plot	Range of infestation	22.5 – 44	26.5 – 29	6 – 12	2.5 – 6
	Average infestation	33	27.5	9.4	4.1

Table 1 shows that there were consistently fewer first generation stings and entries in the diesel oil-dinitrocresol plot than in the check plot. The same relationship persisted at harvest though in a less pronounced degree, as shown in Table 2. The records include dropped fruit as well as picked fruit.

TABLE 2.—YIELD AND INFESTATION AT HARVEST

Plot	Average boxes per tree	Infestation	Stung fruit		Wormy fruit	
			McIntosh	Jonathan	McIntosh	Jonathan
			%	%	%	%
Diesel oil-dinitro-cresol plot	32.5	Range of infestation	8 – 19	8 – 10	3 – 12	7 – 20
		Average infestation	13.5	9.8	7.6	12.6
Check plot	26.9	Range of infestation	16 – 42	16 – 22	22 – 46	24 – 32
		Average infestation	26.2	19.9	36	25

These figures represent the difference between profit and loss in the treated and check plots respectively at a cost of approximately 1 cent per box. As pointed out, however, injury to the trees largely discounts the effectiveness of the treatment.

Injury may perhaps be avoided by considering a point in the behaviour of the larva that appears to have been overlooked. This point is its habit

of biting and rejecting the bark of the tree as it prepares a site for its cocoon, just as the first instar larva bites and rejects the cuticle of the fruit as it makes an entry. In view of this habit, it seems reasonable to attempt to kill the mature larva by a stomach insecticide, just as the newly hatched larva is killed by this means. In poisoning the mature larva there are two difficulties; first, the problem of placing the insecticide in position, and second, the resistance of the mature larva to insecticides. On the other hand, a more potent insecticide may be used on bark than on leaves and fruits, and the presence of an insecticidal residue on the bark would not be objectionable. Furthermore loss of deposit by increase of surface area of the bark would be negligible. The fact that mature larvae may be killed by stomach insecticides was suggested by laboratory experiments with arsenicals in 1938. The following year, dinitrocresol was found to be a more effective stomach insecticide than arsenicals, besides acting by contact.

A measure of the persistence of the toxicity of dinitrocresol is indicated by the following results. One hundred first generation larvae emerging from fruit in July were placed on large limbs that had been treated 100 days previous with 2% dinitrocresol-diesel oil solution. Of these, 18 were recovered as living pupae. On the untreated check limbs, however, 70 were recovered as living pupae.

In corrugated paper bands treated with the same solution 100 days previously, 30 of 100 introduced larvae died as larvae, 47 died as pupae and 14 moths that emerged died without ovipositing. In the untreated check bands only 1 larva succumbed and the moths that emerged oviposited normally. A similar experiment was carried out with bands treated 210 days previous to the introduction of larvae. Of 70 larvae liberated into treated bands, 48% died, whereas of 129 larvae in untreated bands only 0.8% died.

The lethal nature of dinitrocresol in the absence of oil was indicated by another experiment in which corrugated paper bands were dipped in a 2% water suspension of dinitrocresol. Of the 47 larvae introduced into these bands when dry, 83% died within 5 days, while in untreated check bands there was no mortality.

DISCUSSION

Although the practice of killing mature codling moth larvae by oil solutions is not new, no satisfactory evidence of its effectiveness in terms of infested fruit appears to have been provided heretofore. The main experiment described in this paper involved 5½ acres. It has shown that under conditions of heavy infestation and where the trees have not been scraped, a single dormant application of an oil solution of dinitrocresol to trunks and main limbs is highly effective in reducing the degree of codling moth infestation at harvest. Such a procedure in fact appears to be a valuable supplement to the usual summer sprays. It has a serious fault, however, in the tendency of the oil carrier to injure the trees, but this fault does not appear to be insurmountable and further experiment along two lines is indicated.

In the first place, evidence has been provided that when used as a solvent for dinitrocresol, a light petroleum fraction such as kerosene is more likely to cause cambium injury than a heavier so-called diesel fraction of 40 to 45 S.S.U. viscosity. Furthermore, substances such as dinitrocresol and dinitrocyclohexylphenol are more soluble in yet heavier fractions such as, for example, dormant oil of 110 S.S.U. viscosity. Again, cheap oils of a low degree of refinement appear to be better solvents for such compounds than more expensive oils of a higher degree of refinement. Accordingly it may be possible to use an inexpensive oil of sufficient solvent power so that, instead of 100% oil concentration, an emulsion of perhaps 10 or 20% would be adequate. It has been determined that diffusion of the toxicant from oil to water can. for all practical purposes, be prevented by acidification of the water.

In the second place, preliminary experiments have suggested that it may be feasible or even preferable to attack the mature larva not after, but before, it has formed its cocoon. It has been determined that dinitrocresol acts on the mature larva as a stomach insecticide as well as a contact insecticide. This double action is made possible by a characteristic in the behaviour of the insect that so far appears to have been overlooked. Preparatory to forming its cocoon, the mature larva commonly chews and rejects the bark, just as, in effecting an entry, the first instar larva chews and rejects the cuticle of the fruit. Consequently if a deposit of dinitrocresol or some equally effective substance can be placed sufficiently far within the crannies of the bark in June or early July, any first generation larvae that escape the usual "first brood" sprays will again be subjected to insecticidal attack. Since surviving first generation larvae have an importance out of all proportion to their numbers, the significance of the successful outcome of such a procedure would appear to be very considerable. Experiments at Vernon have shown that residues of dinitrocresol retain their toxicity to a considerable degree for many weeks after application to the bark, so it is possible that a treatment in June would still be moderately effective against cocooning larvae in September or October.

A summer trunk treatment, particularly with reference to the effects of dinitrocresol as a stomach insecticide, may be valuable in yet another way. Limited investigation suggests that dinitrocresol applied as a water suspension is toxic to cocooning larvae. If an adjuvant can be found that will effectively carry such a suspension into the crevices of the bark, it may be possible to avoid the use of an oil entirely. Moreover if oil is not found necessary, the cost of treatment would be so reduced that a second application in the fall would not add greatly to the orchard overhead.

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RECENT PROGRESS IN CODLING MOTH CONTROL IN BRITISH COLUMBIA[1]

II. KILLING THE ADULT

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In Part I of this progress account there is a brief introductory discussion of the codling moth problem in British Columbia, which need not be repeated here. It is however stressed again that the object of these reports is to enlist the aid of other investigators in realizing commercial application of two encouraging procedures in codling moth control that, so far as can be determined, have not heretofore been demonstrated by large scale experiment in this country. Part II deals with control of the insect by spray applications directed not against the first instar larva as in the methods currently applied, but against the moth itself.

HISTORICAL

Although much has been written about capture of codling moths in baits, little attention has been paid to the point that, since the moths evidently visit baits to feed, it might be possible to kill them by use of a suitable stomach insecticide.

Strickland (7) recommended the use of a molasses-quassia-arsenical bait for the destruction of noctuid moths. Control of the corn ear worm moth by use of a sugar bait containing potassium antimony tartrate was described by Burdette (3).

Böhmel (1) reported that certain tortricid moths with functional probosces were killed by ingestion of insecticidal bait even after it had dried. The moths evidently liquefied and then absorbed the bait. Bramstedt (2) sprayed apple trees with 4% sugar solution and derris. He claimed better codling moth control than with lead arsenate used in the usual way and concluded that the sweetened derris residue killed the moths rather than the larvae. Hough (5) reported that codling moths were killed by nicotine spray, but made no reference to its action as a stomach poison.

Doinikov (4) found that codling moth infestation was materially lessened by spraying trees every evening with a small amount (1 litre per tree) of 0.5% solution of sodium silicofluoride. His laboratory investigations had previously revealed that nicotine sulphate, arsenious fluoride, and barium chloride solutions were all toxic to the codling moth adult.

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In 1937 the writer determined that the adult codling moth could be killed by a stomach insecticide. It was not until 1940 however, with the use of dinitrophenol derivatives, that this lead was actively followed up. The account that follows touches upon the most interesting results of laboratory and field investigations of 1940 and 1941.

EXPERIMENTAL PROCEDURE

Laboratory experiments were undertaken to determine to what extent the adult codling moth ingests liquids, and whether other substances besides soluble arsenicals are lethal. Individual moths were fed measured amounts of liquids by means of a tuberculin syringe graduated to 0.01 ml. Accurate measurement was obtained by operation of a micrometer screw applied against the plunger of the syringe. The tip of the needle was filed off squarely so that only a very small droplet was exposed and hence evaporation was at a minimum. Some moths were offered indicator solutions in order to estimate the reaction of the alimentary tract. These were dissected and examined after varying periods of time.

In the orchard, wire screen cages were attached to individual limbs which had been sprayed with substances that had been found toxic to the moths in the laboratory. Known numbers of moths were liberated in the cages and frequent observations then made to determine the rate at which they succumbed, and the number of eggs that were deposited.

For a field experiment, a 2-acre block of 10-year old McIntosh was selected. This orchard, 100 yards removed from neighbouring orchards, had not been sprayed for several years, and in 1939 and 1940 the crop had been a total loss from codling moth attack. With the exception of 5 trees in one corner, the block was sprayed in 1941 with a solution of sodium dinitrocresylate made by adding 3,5-dinitro-orthocresol to a hot water solution of sodium carbonate. The concentration, as dinitrocresol, varying somewhat from application to application, averaged 4.1 ounces per 100 Imperial gallons (120 U.S. gallons). For each of 11 applications commencing at petal-fall and continuing until 2 weeks before harvest, about 5 gallons of spray were used per tree. This is about half as much as necessary for a lead arsenate application. At the end of first generation larval attack and again at harvest after second generation attack, records of infestation were taken.

In a second orchard, an experiment was undertaken during the flight of first brood moths in August, in order to determine if dead moths are readily recovered under trees sprayed with substances toxic to the moths. Four plots of 12 large trees each were used. Three of the plots were sprayed twice, while the fourth was not sprayed and served as a check. Cotton cloths, each with an area of 270 square feet, were placed under 1 tree in each plot and frequent observations then made to record and remove dead insects.

Materials

Specifications so far as available, and sources of supply of the chief chemicals employed in this work are as follows: 3,5-dinitro-ocresol, M.P. 81.5°–83° C.; water soly. (25° C.) 0.0176 g./100 ml.; pH after 24 hours 3.4; ash 0.81%.; Standard Agricultural Chemicals, Hoboken, N.J. Ammonium

dinitrocresylate, not over 2% moisture, American Cyanamid and Chemical Corp., Azusa, Calif. Bentonite, granular, Wyodak Chemical Co., Los Angeles, Calif. Sodium carbonate, $Na_2CO_3 . 10\ H_2O$. Sodium silicofluoride, Na_2SiF_6, commercial grade.

RESULTS

Laboratory Experiments

Codling moth adults were found to ingest water solutions quite freely, but generally not for 2 days or more after emergence. Three to 5 minutes were required to satisfy the moth and in this time amounts of liquid up to 0.01 ml. were taken. Sucrose solution containing eosin was readily detected in the crop by dissection. Water solution of dinitrocresol or its sodium salt was freely taken up and readily located in the alimentary tract by coloration. Sticky or even apparently dry residues such as those from aphid excretion may evidently be fed upon by the moth. This seems to be accomplished by ejection and reabsorption of salivary fluid.

Moths that fed upon molasses-water containing derris powder, quassia extract, phenothiazine, potassium antimony tartrate, lead arsenate or cryolite were not noticeably affected. On the other hand 0.02% dinitrocresol solution was obviously lethal although its effects did not generally appear in less than 24 hours. Sodium dinitrocresylate solution appeared to be more freely imbibed than dinitrocresol solution and to be somewhat less toxic. Sodium silicofluoride solution 0.3% was definitely toxic.

Moths ingesting water that had been sprayed on foliage bearing a dry residue of lead arsenate showed no ill effects. On the other hand a dry dinitrocresol residue wetted by water was found to be toxic. Furthermore a dry lead arsenate-dinitrocresol residue appeared to be as toxic as one of dinitrocresol alone. Oviposition too was evidently influenced by dinitrocresol residues. The last points are brought out in Table 1. In this experiment approximately 55 moths were used with each spray mixture.

TABLE 1.—TOXICITY OF WATER-WETTED RESIDUES TO CODLING MOTH ADULTS

Materials per 100 gallons		Mortality after			Average eggs per female
		4 days	7 days	10 days	
		%	%	%	
Dinitrocresol	0.19 lb.	73		95	1.8
Dinitrocresol	0.37 lb.	57	95	100	0.4
Lead arsenate Dinitrocresol	3.75 lb. 0.37 lb.	44	90	93	0.4
Lead arsenate	3.75 lb.	1	21	57	16.6
Check—water only		6	24	35	10.0

Although lead arsenate appeared to be innocuous to the moth, a dilute solution of sodium arsenate was distinctly toxic. Evidently the lead compound remained insoluble. Whereas Marshall (6) found the digestive fluids of the codling moth larva to be distinctly alkaline, the present investigation indicated that those of the adult are acid. The fact that there is limited evidence that calcium arsenate is measurably toxic to the moths may be significant in this connection.

Cage Experiments

The orchard experiments with moths confined to large screen cages on individual branches involved over 1,800 moths. A summary of the more significant results is given in Table 2.

TABLE 2.—LONGEVITY OF MOTHS AND OVIPOSITION IN ORCHARD CAGES

No. of moths	Spray materials per 100 Imperial gallons	Average longevity in days		Average eggs per female
		Females	Males	
400	Dinitrocresol 4.1 oz. Sodium carbonate 8.3 oz. Bentonite 2 lbs.	6.7	4.8	1.5
153	Same except no bentonite	7.7	7.0	1.4
250	Sodium silicofluoride 3 lb.	5.3	4.0	1.0
125	Lead arsenate 3.75 lb.	11.8	9.6	23.8
147	Check—no spray	15.5	12.2	19.7

It is evident that as in the laboratory experiments, moths were definitely affected in large orchard cages by residues of sodium dinitrocresylate and sodium silicofluoride but not by lead arsenate.

Orchard Spraying Experiments

The experiment to show the effect of "moth sprays" under orchard conditions was carried out during cool rainy weather, so differences in recoveries are less pronounced than might otherwise have been the case. Nevertheless, as suggested by Table 3, even under the circumstances prevailing the applications did exert a measurable effect on the moth population.

TABLE 3.—EFFECT OF "MOTH SPRAYS" ON CODLING MOTH POPULATION OF INDIVIDUAL TREES

Materials per 100 Imperial gallons	Dead moths taken beneath one tree per plot, Aug. 3 – Sept. 2		
	Female	Male	Total
Dinitrocresol 4 oz. Sodium carbonate 8 oz.	18	18	36
Ammonium dinitrocresylate 4 oz. Cryolite (synthetic) 3.75 lb.	19	27	46
Sodium silicofluoride 3 lb.	22	10	32
Check—no spray	3	1	4

In this experiment the trees were capable of bearing a crop of 30 to 40 boxes each and the area occupied by the recovery cloths beneath the trees was less than $\frac{2}{3}$ of that overhung by branches. Since, as far as could be determined, the crop and infestation on each of the trees concerned were fairly similar, it follows that in reality perhaps 50 to 60 more moths per tree were quickly eliminated where dinitrocresol sprays were applied than in the check trees.

From the main orchard experiment involving 2 acres, the records of infested fruit at the end of first generation attack and again at harvest are summarized in Tables 4 and 5.

TABLE 4.—FIRST GENERATION INFESTATION RECORDS, July 2

Plot	Materials per 10 Imperial gallons	Trees checked	Average wormy fruit
			%
1	Dinitrocresol 4.1 oz. Sodium carbonate 8.2 oz.	8	1.7
2	Dinitrocresol 4.1 oz. Sodium carbonate 8.2 oz. Bentonite 2 lb.	11	1.5
3	Check—no spray	5	14.5

Moth flight probably had a greater influence on infestation than in the usual larvicidal experiments, for longevity in the sprayed area was probably considerably less than in the check trees. Accordingly it is unlikely that differences in infestation between check and sprayed trees convey an exaggerated impression of the effectiveness of the spray mixtures.

Differences in infestation at harvest were not as great as those of purely first generation. But in view of the facts that infestation in the district as a whole was greater in 1941 than 1940, and that the 1940 crop of the experimental block had been a total loss from codling moth attack, the results are encouraging. They are particularly so when it is considered that so far as has been determined, the sprays used in the experiment were innocuous to codling moth eggs and larvae. The cost of these mixtures is less than 10 cents per 100 gallons and it is possible that they may be added directly to the customary lead arsenate or cryolite larvicidal mixtures.

TABLE 5.—INFESTATION AND SIZE OF FRUIT AT HARVEST

Plot	Materials per 100 Imperial gallons	Trees checked	Average apples per box	Average wormy fruit
				%
1	Dinitrocresol 4.1 oz. Sodium carbonate 8.2 oz.	5	72	20
2	Dinitrocresol 4.1 oz. Sodium carbonate 8.2 oz. Bentonite 2.0 lb.	5	82	24
3	Check—no spray	5	115	67

In addition to the variation between infestations on treated and check plots as noted in Table 5 that of the size of fruit seems too obvious to be due to chance. The trees in each of the 3 plots were apparently equally vigorous in 1940 as well as in 1941 and there was no obvious difference in the relative numbers of fruits per tree.

Effect of Spray on Trees

It was found that under dry-belt conditions sodium dinitrocresylate at 6 ounces dinitrocresol equivalent per 100 Imperial gallons, caused a peculiar whitening of the margins of the young leaves when applied one week after full bloom of McIntosh. When the concentration was reduced to 4 ounces, subsequent applications had no apparent effect and the coloration of the leaves became normal after a few weeks. The parent compound appeared to be more injurious than its sodium salt.

Sodium silicofluoride at 3 pounds per 100 gallons caused considerable foliage injury but cage experiments indicated that a concentration of even 1 pound per 100 gallons may be toxic to moths.

DISCUSSION

Experiments have been briefly described concerning 2 periods of vulnerability in the life cycle of the codling moth that commonly have been overlooked. The first period, which is dealt with in Part I, is from the time the mature larva leaves the fruit until it emerges as a moth. The second period occurs during the flight of the moth. Additional research is necessary if these points of vulnerability are to be exploited to advantage. In dealing with the killing of moths for example, the Vernon investigations and those conducted independently and almost simultaneously by Doinikov (4) in the U.S.S.R. raise a number of important questions:

1. Is there sufficient residue left on the fruit from very low concentrations of sodium or ammonium dinitrocresylate solution to offer a hazard to the consumer?

2. If applications of water-soluble compounds were discontinued at the end of first generation attack would any appreciable residue remain at harvest?

3. Are the effects of "moth sprays" directly additive to those of the ordinary larvicides?

4. What is the effect of oil on a combined spray of, let us say, cryolite-ammonium dinitrocresylate?

5. Are other derivatives of dinitrophenol, nicotine, sodium silicofluoride or still other compounds, more satisfactory than dinitrocresol from the standpoints of toxicity to moths and effects on mammals?

6. Will the inclusion in the spray mixture of some such substance as glucose make these sprays more effective?

7. Is it as desirable to apply every evening a small amount of a spray designed to kill the moth only, or to use at much longer intervals heavy applications of spray directed against both moth and larva or perhaps even against moth, egg and larva?

8. Does the use of dinitrocresol invariably cause an increase in the size of the fruit? If so, is the storage-life of the fruit affected?

9. What is the result of addition of dinitrophenol derivatives to lime sulphur spray mixture?

10. Is there a hazard to the operator in the application of dinitrophenol derivatives?

SUMMARY

Laboratory and field investigations conducted at Vernon, British Columbia, have shown that a considerable measure of control of the codling moth may be attained by the use of summer sprays that do not kill the larva but kill the moth itself.

So far, two derivatives of dinitrophenol have been used in the field, namely ammonium dinitrocresylate and sodium dinitrocresylate. It is possible other compounds will prove more suitable.

The effects of these substances may be additive to those of the customary larvicides. Very little material is used, so the cost is low.

Substances such as lead arsenate or cryolite that are toxic to the larva seem to be relatively non-toxic to the moth. On the other hand substances toxic to the moth at low concentration may be innocuous to the larva. Perhaps the fact that the reaction of the alimentary tract is alkaline in the larva and appears to be acid in the moth has some bearing on that point.

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MALTING QUALITY OF CANADIAN BARLEYS

III. TWENTY-EIGHT VARIETIES, 1938, 1939, AND 1940 TRIALS[1]

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This series of papers was started with the object of putting on record summaries of the latest available data on the malting qualities of the principal named varieties in Canadian barley breeding programs. The present paper deals with 28 varieties grown in field trials of the years 1938, 1939 and 1940, and malted and analyzed during the following seasons. Information on 20 of these was included in earlier investigations (2, 6) but these varieties have been studied further, either because earlier data were considered inadequate or because the variety was of sufficient importance to merit inclusion in later studies for purposes of comparison. No data on the remaining 8 varieties have been published previously in Canada.

During recent years there has been a trend towards the inclusion of more new hybrid lines and fewer named varieties in Canadian malting investigations. As a result, only 362 samples of named varieties are considered in this paper, whereas data on 516 were summarized in part II (6). Nevertheless, though the number of new samples studied was relatively small, considering the number of varieties represented, it seems advisable to put the data on record for the information of plant breeders who may be using some of the varieties in their work.

The criteria of malting quality and the limitations of the laboratory malting test, described in Part II (6), should be kept in mind in reading the remainder of this paper, in which the results of malting tests made on 362 samples of barley, representing 28 varieties, are discussed.

MATERIALS

The barley samples were collected from 11 investigations made during 1938 and 1939 and from 2 investigations made during 1940. The material submitted from the 1940 crop for malting tests has shown a marked increase in hybrid lines and little additional information on named varieties was obtained from the 1940 crop. However, in order to provide data on Chevron, two small tests made in 1940 are included in this paper.

A larger number of samples than could be malted were grown in the various field tests and it was therefore necessary to follow the usual procedure of selecting samples representing certain varieties and stations for malting studies. Table 1 shows the identity and size of the malting tests,

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for each investigation. The directors and sponsors of each agronomic investigation are also listed, as the authors wish to express their appreciation for the co-operation of the plant breeders and the companies or institutions financing the agronomic tests.

TABLE 1.—DESCRIPTION OF INVESTIGATIONS

Inv. No.	Year	No. in test		Stations	Under the direction of	Financed by
		Varieties	Stations			
1	1938	10	4	Navan, Kinburn, Ottawa, Merrickville	Mr. P. R. Cowan	Dom. Dept. of Agriculture
2	1938	8	6	Swan River, Somerset, Gretna, Solsgirth, Ochre River, Holland	Dr. P. J. Olson	Manitoba Dept. of Agriculture, United Grain Growers Ltd., Canada Malting Co., Dominion Malting Co.
3	1938	6	6	Olds, Fallis, Beaverlodge, Bon Accord, Warburg, Edmonton	Dr. K. W. Neatby	United Grain Growers Ltd.
4	1938	24	6	Ste. Anne de la Pocatiere, Fredericton, Nappan, Winnipeg, Brandon, Lacombe	Mr. P. R. Cowan	Dom Dept. of Agriculture
5	1939	19	2	Bowsman, Winnipeg	Dr. P. J. Olson	Manitoba Dept. of Agriculture, United Grain Growers, Ltd., Canada Malting Co., Dominion Malting Co.
6	1939	10	1	Winnipeg	Dr. P. J. Olson	
7	1939	6	1	Swan River	Mr. W. H. Johnston	Dom. Dept. of Agriculture
8	1939	23	1	Macdonald College	Prof. E. A. Lods	National Breweries Ltd. Molson's Brewery, Canada Malting Co.
9	1939	12	3	Gilbert Plains, Brandon, Winnipeg	Mr. P. R. Cowan	Dom. Dept. of Agriculture
10	1939	8	6	Olds, Mellowdale, Fallis, Warburg, Bon Accord, Beaverlodge	Dr. K. W. Neatby	United Grain Growers Ltd.
11	1939	6	11	Peterboro, Hagersville, Paris, Ailsa Craig, Ingersoll, Galt, Norwich, Beaverton, Kinkora, Oakwood, Port Hope	Dr.G.P.McRostie	Ontario Agricultural College
12	1940	3	1	Winnipeg	Dr. J. P. Olson	Manitoba Dept. of Agriculture, United Grain Growers Ltd., Canada Malting Co., Dominion Malting Co.
13	1940	45	1	Star City	Dr. J. B. Harrington	United Grain Growers Ltd., Canada Malting Co.

The agronomic investigations were carried out as in former years (2, 6) and the grain from the replicate plots was bulked to provide the 1200 gm. sample required for the malting tests.

METHODS

Malting

The samples were prepared for malting and malted by standard methods (3) and with equipment which has been described previously (1, 3). The practice of carrying out malting tests in duplicate has been discontinued, except in special tests, owing to the small order of differences between duplicates, and the desire of the plant breeders to have more samples malted.

Analytical

All barley nitrogen and 1000-kernel weight determinations were made in the Malting Laboratory by the methods given in Part II (6). The malt analyses were also carried out by the standard methods described in Part II (6). Total wort nitrogen was determined in place of permanently soluble wort nitrogen, as these determinations give comparable results (5) and the former is simpler to make.

RESULTS

The data from the determinations made on the 362 samples of barley and the malts made from them are so numerous that they may be usefully presented only in summary form. As noted in Part II (6) the authors consider that the interpretation of results rather than the presentation of masses of data is the chief function of papers in this series.

Only the comparative malting qualities of the varieties are discussed in this paper. The investigations also yielded information on the effect of environment on malting quality and the differential effect of environment on varieties, but these effects are not discussed in this paper.

The differential effect of seasons on varieties is worthy of mention. No specific comparisons between seasons are made, but it should be noted that data given in Parts I (2) and II (6) and in this paper show that the varieties are placed in essentially the same relative positions with respect to malting quality in each year. This lack of interaction between seasons and varieties agrees with results obtained in the United States (4).

As with previous crops, significant varietal differences were not demonstrated with respect to the 5 minor determinations made on the malts. These may be conveniently listed along with their mean values: moisture content, 3.8%; odour of mash, very aromatic; time of conversion, less than 5 minutes; speed of filtration, normal; colour of wort, 1.6 Lovibond units.

The clarity of wort has received special attention since the last paper was published. Distinct varietal differences have been demonstrated in this quality and will be reported elsewhere. It seems sufficient to mention in this paper that Peatland, Gartons, Gartons' selection, Byng, Plush, Ottawa E.25, Wisconsin 38, York and Charlottetown 80 yielded distinctly cloudy worts in comparison with those from O.A.C. 21. Trebi, Regal,

Sannalta and Prospect produced relatively turbid worts, but their differences from O.A.C. 21 were not statistically significant in all studies. This no doubt reflects the effects of environmental conditions.

As in previous tests, significant varietal differences were demonstrated with respect to 8 major barley, malting and malt properties. The mean values for O.A.C. 21, the standard variety, for each of these determinations and for each investigation are given in Table 2. Data for the remaining 27 varieties are summarized in Table 3, where they are reported as differences between the mean for the variety in question and the corresponding mean value for O.A.C. 21 in the same investigation. A negative sign indicates that the value for the variety in question was less than that for O.A.C. 21 and a positive sign indicates that it was greater.

TABLE 2.—MALT, MALTING, AND BARLEY PROPERTIES OF O.A.C. 21, MEAN VALUES FOR EACH OF THIRTEEN INVESTIGATIONS

Inv. No.	No. of samples	Malt			Malting		Barley		
		Extract	D.P.	Wort N.	Loss	Sprouts	Total N.	1000-K Weight	Plump barley
		%	°L.	%	%	%	%	gm.	%
1	4	74.1	121	1.13	8.1	3.2	2.18	32.4	74.1
2	6	74.3	143	1.11	8.9	3.8	2.35	30.4	70.6
3	6	72.4	133	1.03	8.2	3.4	2.35	32.6	73.0
4	6	75.0	116	1.06	8.2	3.8	2.08	31.8	76.9
5	2	72.2	136	1.16	9.0	3.1	2.57	30.9	67.2
6	1	74.1	173	1.24	9.2	4.1	2.61	34.8	90.8
7	1	73.7	113	1.04	9.3	3.7	2.24	31.4	62.0
8	1	77.2	98	1.09	9.1	3.8	2.03	35.4	89.0
9	3	72.1	153	1.29	9.4	3.7	2.52	30.4	56.6
10	6	75.3	134	1.13	10.5	5.1	2.14	32.8	79.6
11	11	75.9	121	1.22	11.4	5.5	2.02	33.0	78.3
12	1	73.3	154	1.23	10.2	3.2	2.57	31.0	59.0
13	1	73.6	177	1.38	12.5	6.3	2.61	36.2	88.2
Weighted mean	49	74.4	131	1.14	9.6	4.2	2.23	32.2	74.5

Statistical analyses were carried out on all sets of data for individual investigations to which such treatment was applicable. From these, the differences between varieties that would occur only once in 20 times due to chance were calculated, and it was assumed that differences greater than these indicated real differences between the varieties. The differences for the individual investigations that may be considered significant are marked with an asterisk in Table 3. The necessary differences are not the same for all investigations, as the magnitude of necessary differences generally decreases with increasing size of investigation.

The data in Tables 2 and 3 are summarized in Table 4 to provide one line of data for each variety. The weighted mean values for each determination are given for O.A.C. 21 and all other figures are the weighted mean differences between the standard and the other varieties. These data provide the basis for the discussion of the comparative malting qualities of the varieties.

TABLE 3.—COMPARATIVE MALT, MALTING AND BARLEY PROPERTIES OF VARIETIES EXPRESSED AS DIFFERENCES BETWEEN MEAN VALUES FOR EACH VARIETY IN EACH INVESTIGATION AND CORRESPONDING MEAN VALUES FOR O.A.C. 21

Class	Variety	Inv. No.	No. of samples	Malt			Malting		Barley		
				Extract	D.P.	Wort N.	Loss	Sprouts	Total N.	1000-k. weight	Plump barley
				%	°L	%	%	%	%	gm.	%
Rough-awned, 6-rowed, admitted to malting grades	Mensury	1	4	−0.2	6	0.02	0.2	−0.1	0.08	0.4	0.3
		4	6	0	2	0.01	−0.5	−0.2	−0.02	0.1	1.5
		9	3	0.1	7	−0.01	0.4	0.4	0.07	0.9	2.8
		10	6	0	8	0.02	0.7	0.3	0.03	0.3	3.0
		11	11	0.4	6	−0.01	0.2	−0.1	0.01	0.8	6.2
	Olli	3	6	3.0*	24*	0.13*	0.6	0.2	0	−0.6	−1.4
		4	6	2.1*	27*	0.05	0.2	0.2	−0.08	−2.2*	−8.9
		10	6	3.1*	2	−0.01	0.8	0.1	−0.08	−0.6	−0.7
Other rough-awned, 6-rowed	Brio	3	6	2.0*	− 7	0.07*	−0.5*	−0.8*	−0.02	−1.0	4.4
		10	6	2.1*	− 9	0.01	0.4	−0.6*	−0.14*	−2.2*	5.5
	Chevron	12	1	−3.8	72	0.22	−0.6	0.5	0.69	−5.7	−32.9
		13	1	−1.2	74	0.16	0.3	0.3	0.35	−4.8	−13.7
	Gartons	6	1	−1.0	−16	0.05	−0.7	−1.3	0.15	−2.0	− 0.4
		9	3	−2.1*	29*	0.13	0.3	−0.2	0.54*	−2.2	−11.0
		10	6	−0.8	− 3	−0.01	−0.4	−0.5*	0.16*	−1.6*	− 4.7
	Gart. sel.	9	3	−1.2*	35*	0.18*	−0.3	−0.6*	0.57*	−1.8	− 8.8
	Peatland	1	4	−0.6	−11*	0	0.3	−0.2	0.23*	−3.6*	− 3.8
		2	6	−0.5	− 1	0.04	−0.2	−0.5*	0.26*	−0.7	1.3
		3	6	−1.7*	11	0.17*	0.3*	0	0.44*	−5.1*	−25.5*
		4	6	−0.7	8	0.04	−0.1	0	0.26*	−2.6*	− 4.2
		5	2	−1.3*	14	0.10	−0.1	−0.1	0.39*	−4.1*	−15.8
		9	3	−2.1*	22*	0.11	−0.7*	−0.7	0.36*	−6.4*	−33.9*
		12	1	−1.3	9	0.10	0.2	0.5	0.33	−4.2	− 8.7
	Pontiac	4	6	−1.0	8	−0.04	−0.5	−0.4*	−0.04	0	3.7
		8	1	−1.2	−18	−0.16	−2.1	−1.1	−0.15	0.5	5.3
	Trebi	4	6	−0.8	−24*	−0.26*	−1.6	−1.2*	−0.20*	8.2*	10.8
		10	6	1.0	−35*	−0.33*	−1.0*	−0.9*	−0.26*	9.2*	13.6*
Smooth-awned 6-rowed	Alberta 8	4	6	−1.4*	−27*	−0.10*	−0.6*	−0.4*	−0.05	1.8	5.7
	Br. 216	4	6	1.2*	−10	−0.02	0.2	0.4*	−0.18*	−7.4*	−31.6*
	Byng	4	6	−0.4	−42*	−0.30*	−1.9*	−1.2*	−0.18*	2.1*	10.8
		8	1	0	−44	−0.32	−3.0	−1.2	−0.11	1.4	4.2
		11	11	0.4	−42*	−0.33*	−1.3*	−1.5*	−0.16*	3.6*	16.1*
	Newal	3	6	−1.6*	37*	−0.01	−1.3*	−1.0*	0.15*	4.2*	18.7*
		4	6	−2.2*	33*	−0.06	−1.5*	−1.2*	0.09	2.4*	18.3*
		10	6	−1.1*	36*	−0.08	−0.6	−0.8*	0.11	3.5*	15.3*
		11	11	−2.1*	20*	−0.08*	−1.0*	−1.2*	0.09*	3.2*	16.9*
	Nobarb	1	4	−1.8*	−38*	−0.27*	−0.8*	−0.5*	−0.07	−0.7	−1.4
		4	6	−0.8	−23*	−0.23*	−0.9*	−0.6*	−0.17*	0.8	2.4
		11	11	−0.9*	−27*	−0.23*	−1.4*	−1.3*	−0.01	4.7*	17.3*
	Ott.E.25	4	6	−3.7*	−20*	−0.19*	−1.9*	−1.0*	0.12*	5.8*	17.1*
	Plush	4	6	−1.6*	−40*	−0.25*	−1.7*	−1.1*	−0.11	2.0	4.5
		7	1	−1.3*	−37	−0.20	−2.3	−1.2	−0.04	3.4	22.0
		9	3	−1.5*	−24*	−0.23*	−1.4*	−0.5*	0.17*	4.9*	23.0*

TABLE 3.—COMPARATIVE MALT, MALTING AND BARLEY PROPERTIES OF VARIETIES EXPRESSED AS DIFFERENCES BETWEEN MEAN VALUES FOR EACH VARIETY IN EACH INVESTIGATION AND CORRESPONDING MEAN VALUES FOR A.O.C. 21—*Concluded*

Class	Variety	Inv. No.	No. of samples	Malt			Malting		Barley		
				Extract	D.P.	Wort N.	Loss	Sprouts	Total N.	1000-k. weight	Plump barley
				%	°L	%	%	%	%	gm.	%
Smooth-awned 6-rowed	Prospect	4	6	−3.1*	−25*	−0.22*	−1.2*	−0.8*	−0.05	3.2*	15.1*
	Regal	3	6	−2.2*	−40*	−0.04	−0.8	−0.6	0.11*	1.8	5.0
		4	6	−2.2*	−39*	−0.11*	−0.9*	−0.8*	−0.01	−0.6	− 1.7
		10	6	−1.8*	−37*	−0.03	0.3	−0.5*	0.08	1.4*	5.0
		11	11	−2.2*	−38*	−0.05*	−0.5	−0.8*	0.12*	0.8	13.6*
	Sask. 264	4	6	−0.5	−16*	0.02	0.5	0.2	−0.01	0.4	−16.4*
	Velvet	1	4	−2.4*	−17*	−0.06	0	−0.2	0	−1.9	− 7.8
		4	6	−1.3*	− 2	−0.02	−0.7*	−0.4*	0.02	−1.2	5.1
		8	1	−0.9	−28	−0.09	−1.4	−1.0	−0.07	−0.6	6.0
	Wis. 38	4	6	−3.2*	−23*	−0.20*	−0.8*	−0.7*	−0.03	1.0	13.6*
		7	1	−2.1	−37	−0.23	−1.7	−1.5	−0.12	1.2	28.0
	York	4	6	−1.2*	−16*	−0.16*	−1.6*	−1.4*	0	−0.4	1.9
Rough-awned, 2-rowed	Hannchen	4	6	2 4*	− 5	−0.06	0.2	−0.2	−0.09	0.8	− 7.5
	Ch. 80	4	6	2.0*	−22*	−0.10*	0.4	0.2	−0.03	2.0	5.8
	Victory	4	6	1.8*	−23*	−0.20*	−0.2	−0.2	−0.12*	2.6*	2.1
Smooth-awned, 2-rowed	Rex	4	6	0.4	3	0.06	−0.1	−0.2	0.09	4.9*	5.3
	Sannalta	4	6	0.6	− 4	−0.02	−0.5	−0.5*	0.05	7.4*	18.7*

* Values significantly above 5% level.

DISCUSSION

The terms used in this discussion are self-explanatory to those who are in contact with the various barley and malting investigations and to others interested in them. However, it seems advisable to explain that the term "enzymatic properties" which is used in various instances for convenience refers to diastatic power and wort nitrogen content. These determinations provide information on the activity of the saccharifying and proteolytic enzymes.

The data in Table 4 show that among the rough awned varieties now admitted to the malting grades, Mensury must be considered equal in quality to O.A.C. 21 with respect to all properties measured. Olli also has favourable characteristics in that it is high in extract and in the enzymatic properties. In the tests under discussion these factors appear to more than counterbalance the somewhat low kernel weight of Olli, and on the whole this variety appears reasonably satisfactory. The tendency of Olli to produce small kernels under some conditions should restrict its production. Agronomically it is suitable for northern areas, owing to early ripening habit, and appears to show its best qualities in Northern Alberta.

Among the other rough awned varieties Brio and Pontiac approach closest to, but are not equal to, O.A.C. 21 in quality. Brio tends to be somewhat low in diastatic power and it may also be faulted for producing somewhat small kernels. Pontiac is faulted in extract and tends to be somewhat low in growth rate and wort nitrogen content, indicating some enzymatic deficiencies. Gartons[5], Gartons' selection, Peatland and Chevron are all characterized by high barley nitrogen content and low kernel weight. These factors are also reflected in low values for malt extract and high values for diastatic power and wort nitrogen content. When comparisons with O.A.C. 21 are made at equal nitrogen content, Gartons and Peatland show deficiencies in diastatic power and wort nitrogen content, Gartons' selection shows a deficiency in wort nitrogen content and only Chevron shows high values in both properties. These four varieties are considered inferior in malting quality to O.A.C. 21. The deficiencies of Trebi are very obvious, as despite its relatively high malt extract yield the values for the enzymatic properties are very low.

Thirteen smooth awned 6-rowed varieties were tested, and among these Brandon 216 seems outstanding in malt qualities. However, from the commercial viewpoint it is not a promising variety owing to its low percentage of heavy grade barley and low kernel weight. Saskatchewan 264, which was produced from a cross between a smooth awned 6-rowed and a 2-rowed parent, is another outstanding variety in the smooth awned group. However, Saskatchewan 264 is low in diastatic power and in percentage heavy grade barley. These two varieties, Brandon 216 and Saskatchewan 264, cannot be regarded as equal to O.A.C. 21 in malting quality. The remaining 11 varieties in the group exhibit slow growth rates and enzymatic deficiencies. Byng appears equal to O.A.C. 21 in extract yield but it is deficient with respect to diastatic power and wort nitrogen content. Newal is characterized by an extremely high diastatic power, which is still high when allowance is made for the high nitrogen content of this variety, but it is low in extract yield and tends to be low in wort nitrogen content. Nobarb, Plush, York and Alberta 8 are similar in characteristics, all being low in extract, diastatic power and wort nitrogen, though Alberta 8 is not faulted in the last quality to the same extent as the other varieties. Regal is quite low in extract and diastatic power but it is not as low in wort nitrogen content as most others in the group. Velvet is faulted in extract and diastatic power but approaches the value for O.A.C. 21 in wort nitrogen content, and on the whole its enzymatic properties are the least unsatisfactory in this group. Ottawa E.25, Prospect and Wisconsin 38 are the poorest malting varieties in the smooth awned group.

As was noted in Part II (6), data on 2-rowed varieties are only of theoretical interest as they do not modify readily. Hannchen is used to some extent for malting in the United States and may be used as a standard with which to compare the 2-rowed varieties. These all possess the high kernel weights of this class and are somewhat low in enzymatic activity. Hannchen appears to be somewhat similar to O.A.C. 21 in most properties. Charlottetown 80 and Victory may be regarded as inferior to Hannchen owing to low values for diastatic power and wort nitrogen content.

[5] The Board of Grain Commissioners has recently announced that after July 31, 1942, Gartons will not be eligible for grades higher than 3CW six-row.

Rex and Sannalta, which are smooth awned varieties, are higher than Hannchen in kernel weight, but they appear to modify less readily than it, as is shown by their low values for malt extract. They appear anomalous in this respect, as values for diastatic power and wort nitrogen content suggest that these varieties have satisfactory enzymatic properties. Pending further information on these points, both varieties are classed as inferior to Hannchen for malting purposes.

There is little to add to the comments in Part II (6) on the merits of the smooth awned group as malting varieties. It is evident that the common varieties of this type are characterized by low enzymatic activity, but some of the newer types show improvements in one property. Others, such as Brandon 216 and Saskatchewan 264 are decided improvements, although they are not equal to O.A.C. 21 in malting quality. Brandon 216 is of particular interest, in that it is faulted in physical rather than chemical characteristics. The principal objection to Saskatchewan 264 is also physical, as it produces a low percentage of heavy grade barley, though it is also faulted to some extent in diastatic power.

The results of these tests provide information on varietal differences in malting quality, as measured by the laboratory malting test. It should be borne in mind, however, that the laboratory malting test does not provide measures of all the qualities that may be required in malting barley and that once varieties approach O.A.C. 21 in the qualities measured in the test other tests must be undertaken in order to obtain a final evaluation of the varieties for purposes of commercial malting. The routine laboratory malting test serves mainly to separate the poor from the promising varieties.

TABLE 4.—COMPARATIVE MALT, MALTING AND BARLEY PROPERTIES OF VARIETIES, DIFFERENCES BETWEEN WEIGHTED MEAN FOR EACH VARIETY AND CORRESPONDING WEIGHTED MEAN FOR O.A.C. 21

Class	Variety	Inv. No.	No. of samples	Malt			Malting		Barley		
				Extract	D.P.	Wort N.	Loss	Sprouts	Total N.	1000-k. weight	Plump barley
				%	°L	%	%	%	%	gm.	%
"Standard"	O.A.C.21, Mean	1–13	49	74.4	131	1.14	9.6	4.2	2.23	32.2	74.5
Rough-awned, 6-rowed, admitted to malting grades	Mensury	1, 4, 9–11	30	0.1	6*	0	0.2	0	0.02	0.5	3.5
	Olli	3, 4, 10	18	2.7*	18*	0.06*	0.5*	0.2*	−0.05	−1.1*	− 3.7
Other rough-awned, 6-rowed	Brio	3, 10	12	2.0*	− 8	0.04	0	−0.7*	−0.08*	−1.6*	5.0
	Chevron	12, 13	2	−2.5*	73*	0.19*	−0.1	0.4	0.52*	−5.2*	−23.3*
	Gartons	6, 9, 10	10	−1.2*	5	0.04	−0.2	−0.5*	0.27*	−1.8*	− 6.2
	Gart. sel.	9	3	−1.2*	35*	0.18*	−0.3	−0.6*	0.57*	−1.8	− 8.8
	Peatland	1–5, 9, 12	28	−1.1*	6	0.08*	0	−0.2*	0.32*	−3.4*	−11.7*
	Pontiac	4, 8	7	−1.0*	4	−0.06*	−0.7*	−0.5*	−0.06	0.1	3.9
	Trebi	4, 10	12	0.1	−30*	−0.30*	−1.3*	−1.0*	−0.23*	8.7*	12.2*

TABLE 4.—COMPARATIVE MALT, MALTING AND BARLEY PROPERTIES OF VARIETIES, DIFFERENCES BETWEEN WEIGHTED MEAN FOR EACH VARIETY AND CORRESPONDING WEIGHTED MEAN FOR O.A.C. 21—*Concluded*

Class	Variety	Inv. No.	No. of samples	Malt			Malting		Barley		
				Extract	D.P.	Wort N.	Loss	Sprouts	Total N.	1000-k. weight	Plump barley
				%	°L	%	%	%	%	gm.	%
Smooth-awned 6-rowed	Alberta 8	4	6	−1.4*	−27*	−0.10*	−0.6*	−0.4*	−0.05	1.8	5.7
	Br. 216	4	6	1.2*	−10	−0.02	0.2	0.4*	−0.18*	−7.4*	−31.6*
	Byng	4, 8, 11	18	0.1	−42*	−0.32*	−1.6*	−1.4*	−0.16*	3.0*	13.7*
	Newal	3, 4, 10, 11	29	−1.8*	30*	−0.06*	−1.1*	−1.1*	0.10*	3.3*	17.2*
	Nobarb	1, 4, 11	21	−1.0*	−28*	−0.24*	−1.1*	−1.0*	−0.07*	2.6*	9.5*
	Ott. E.25	4	6	−3.7*	−20*	−0.19*	−1.9*	−1.0*	0.12*	5.8*	17.1*
	Plush	4, 7, 9	10	−1.5*	−35*	−0.24*	−1.7*	−0.9*	−0.02	3.0*	11.8*
	Prospect	4	6	−3.1*	−25*	−0.22*	−1.2*	−0.8*	−0.05	3.2*	15.1*
	Regal	3, 4, 10, 11	29	−2.1*	−38*	−0.06*	−0.5*	−0.7*	0.08*	0.8*	6.9*
	Sask. 264	4	6	−0.5	−16*	0.02	0.5	0.2	−0.01	0.4	−16.4*
	Velvet	1, 4, 8	11	−1.7*	−10*	−0.04	−0.5	−0.4*	0	−1.4*	0.5
	Wis. 38	4, 7	7	−3.0*	−25*	−0.20*	−0.9*	−0.8*	−0.04	1.0	15.6*
	York	4	6	−1.2*	−16*	−0.16*	−1.6*	−1.4*	0	−0.4	1.9
Rough-awned 2-rowed	Hannchen	4	6	2.4*	− 5	−0.06	0.2	−0.2	−0.09	0.8	− 7.5
	Ch. 80	4	6	2.0*	−22*	−0.10*	0.4	0.2	−0.03	2.0	5.8
	Victory	4	6	1.8*	−23*	−0.20*	−0.2	−0.2	−0.12*	2.6*	2.1
Smooth-awned 2-rowed	Rex	4	6	0.4	3	0.06	−0.1	−0.2	0.09	4.9*	5.3
	Sannalta	4	6	0.6	− 4	−0.02	−0.5	−0.5*	0.05	7.4*	18.7*

* Values significantly above 5% level.

SUMMARY

A summary is presented of the comparisons, obtained from malting tests, of each of 27 barley varieties. These were represented by from 2 to 30 samples grown under different environmental conditions in 1938, 1939 and 1940 with comparable samples of O.A.C. 21, the standard malting variety. Reference is made to the limitations of the malting test and varietal differences were demonstrated with respect to 8 important properties. These were: extract yield, diastatic activity and total wort nitrogen content of the malt; malting loss and sprouts; and total nitrogen content, 1000-kernel weight of the barley and percentage heavy grade kernels.

Mensury is considered fully equal to O.A.C. 21 in all properties measured. Olli is considered reasonably satisfactory as its malt properties compare very favourably with those of the standard, and these advantages appear to counterbalance its somewhat low kernel weight. This early variety appears to best advantage when grown in northern districts, particularly in Alberta. Brio and Pontiac are somewhat similar to O.A.C. 21 in general quality, but cannot be considered equal to it for malting purposes. Chevron, Gartons, Gartons' selection and Peatland are all characterized by high nitrogen content and the last 3 also exhibit deficiencies in the enzymatic properties. These are considered inferior to O.A.C.21 in malting quality. Trebi shows marked enzymatic deficiencies and it is not considered suitable for malting. Among the smooth awned 6-rowed varieties, only Brandon 216 and Saskatchewan 264 are not characterized by serious deficiencies in malting quality and even they are not equal to the standard owing to low percentage of heavy grade barley. Byng, Newal, Nobarb, Plush, Regal, Alberta 8, Velvet, York, Ottawa E.25, Prospect and Wisconsin 38 show deficiencies in two or more malt properties. The last three varieties are the most unsatisfactory of the group. The data for the 2-rowed varieties are of limited interest, but it is considered that Charlottetown 80, Victory, Rex and Sannalta are not equal to Hannchen in malting quality.

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A STUDY OF THE INHERITANCE OF SOLID STEMS IN SOME TETRAPLOID WHEATS[1]

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INTRODUCTION

The present work deals with the results of a study of the inheritance of solid straw in wheat hybrids of *Triticum durum* Desf. parentage and of *T. durum* and *T. turgidum* L. parentage. This study was undertaken not only because of its scientific interest, but because of the probable economic importance of the character concerned, and hence, of the significance of the results to the plant breeder.

All the economic varieties of common wheat, *T. vulgare* Vill. (*T. aestivum* L.) grown in the Prairie Provinces of Canada have stems with hollow internodes. The same is true of all but one of the usual varieties of *T. durum*, although the walls of the internodes in the stems of the hollow varieties of *T. durum* are characteristically thicker than those of *T. vulgare*. The stems of the *durum* variety Golden Ball are however almost entirely filled with pithy tissue. One of the important implications of this morphological character is that it gives the variety a high degree of resistance to damage by attacks of the wheat stem sawfly (*Cephus cinctus* Nort.) in contrast to the hollow commercial varieties of *T. vulgare*, which are susceptible to this pest. As the work of Mitchener (15) has shown, the hollow stemmed varieties of *T. durum* are likewise susceptible, though less so than those of *T. vulgare*. The studies of Kemp (9) and of Kemp and Platt (10) show that the plants of solid varieties, or even types having portions of the stem filled with pith, suffer less larval infestation than those of hollow varieties. More important, since the larvae are adapted to a hollow-stemmed host, the pith inhibits their development and downward progress, so that few ever reach the ground level of the stem where hibernation and pupation take place. Still fewer succeed in the critical act, the cutting of the stem from within at the base preparatory to hibernation. Stems thus severed fall over just prior to ripening, and are either lost or harvested at additional labour and expense.

Because of the prevalence of the wheat stem sawfly in the plains region of the Prairie Provinces, where its development as a pest is intensified by strip farming methods recently introduced to control soil drifting, it is desirable to produce a solid-stemmed *vulgare* type wheat of generally suitable economic characteristics. Also, since some farmers continue to produce *durum* wheat, a solid variety of this would be useful to replace Golden Ball, which is satisfactory in yield and sawfly resistance but discriminated against in the trade because of its inferior quality. This study contributes chiefly

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to the theoretical basis of the development of such a wheat. The cytogenetics of pithiness, although not investigated here, is of interest in relation to the problem of transferring the solid character, or even the general tetraploid type of pithiness to varieties of common wheat possessing the standard agronomic and economic characters; therefore the literature on this subject is reviewed and discussed.

REVIEW OF LITERATURE

It is possible to assemble a good deal of literature on the inheritance of pithiness, and most of this has been reviewed in detail (Putnam, 16). In some cases it seems well established that the investigators have reported on pithiness or the solid stem character in the same sense as the term is applied here. In others, it is almost certain that the studies were concerned not with solid stems, but with the general type of pithiness or thick walls characteristic of the emmer or tetraploid group of wheats. Some observations made incidental to the present study lead to the belief that the two conditions should be regarded not as a difference of degree, but as a difference of kind.

Investigations of the inheritance of pithiness (of whatever type) may be classified according to (1) those undertaken on hybrids from crosses between varieties or species within the tetraploid or 28-chromosome group and (2) those on hybrids between the tetraploid and hexaploid or 42-chromosome group. In interspecific crosses involving parents of different chromosome number, the more recent studies have often been correlated with cytological work, and are therefore of special interest.

Intra-tetraploid Crosses

Engledow (2) and Engledow and Hutchinson (3) have used varieties of *T. polonicum* L. and *T. durum* as pithy parents, and varieties of *T. turgidum* and *T. durum* as hollow parents. The genetic results were all attributed to a single factor pair difference. The pithier phenotype of any parental combination was found to be at least partially dominant. Because of the lack of clear distinction between some pithy and intermediate phenotypes, these two classes were usually bulked to form the dominant class, and to produce the usual 3 : 1 ratio. From the varietal names and descriptions given, it is improbable that any of the pithy parents used by the above workers were solid in the sense of having culms completely filled with pith.

Goytia y Angulo (4) used a *durum* variety Obispado which is described by him as solid. In a cross with a hollow *durum* variety, the F_2 hybrids were approximately in the ratio of 1 solid to 15 having various degrees of hollowness. A two-factor hypothesis was therefore suggested, but with reservation.

Crosses Between Tetraploid and Hexaploid Species

Genetic studies.—Genes for pithiness in several tetraploid species have been studied in crosses of those species with *T. vulgare*. Biffen (1), using a *turgidum* parent having a pithy upper internode, reported a ratio of 3 hollow segregates to 1 pithy in the F_2. Kajanus (6, 7, 8) used a *turgidum* variety described as having stems completely filled with pith. In one

cross his results were in agreement with those of Biffen; in another, the dominant hollow class was not large enough to fit the monofactorial ratio. Similarly Stoll, reported by Kajanus (8), found *vulgare* hollowness dominant to *polonicum* pithiness in a 3 : 1 ratio.

On the other hand, Engledow and Hutchinson (3) and von Tschermak (20) as a result of their investigations regard *turgidum* pithiness as dominant in *T. turgidum* × *T. vulgare* hybrids. Engledow and Hutchinson (3), by bulking the pithy and intermediate plants in the dominant class, obtained a 3 : 1 ratio. In hybrids of other tetraploid species and *T. vulgare*, von Tschermak (20) using *T. polonicum* and *T. durum*, Thompson (17) using *T. durum*, and Vavilov and Jakushkina (21) using *T. persicum* all report the tetraploid type of pithiness to occur more frequently than the *vulgare* hollowness in the F_2. None of this latter group of investigators offer factorial hypotheses to interpret their results.

Cytogenetic studies.—Kihara (11), in a study of a small F_2 population from a cross of *T. vulgare* and a solid variety of *durum* wheat, found that the plants forming the increase group, which have more than 35 chromosomes and thus tend to produce progeny returning to the numerically *vulgare* chromosome condition, were all hollow. This group consisted of 5 out of 28 plants. In the decrease group, in the progeny of which the 28-chromosome condition of the *durum* parent tends to be restored, the condition was hollow, intermediate, or solid. A number of the intermediate plants in this group produced progenies which when classified according to stem cavity, produced a ratio which could have been due to a single factor pair difference.

The work of Thompson and Hollingshead (18) on the F_2 of *T. vulgare* × *T. dicoccum* Schrank. is in agreement with that of Kihara as regards the ratio of the distribution of segregates in the increase and decrease groups, and also tends to be in agreement as regards stem cavity types in relation to chromosome number, except that no hollow types were recovered in the decrease group. Thompson, Arnason, and Love (19) found no 28-chromosome hybrids with the hollow thin-walled condition of *T. vulgare*, but did find some small-cavitied tetraploid segregates in F_2 populations. They assume therefore a factor or factors for hollowness in the primary 28 chromosomes (genoms A and B) of the *vulgare* parent.

Matsumura (13, 14) in studies on the F_2 of *T. polonicum* × *T. spelta* L. reported the *polonicum* type of pithiness to be correlated with the *polonicum* chromosome count. All 28-chromosome plants were either pithy or had only very small cavities. Evidence from trisomic plants indicated the presence of a *spelta* gene or genes in one of the chromosomes of the *C* ("D") genom which is characteristic of the hexaploid wheats.

Yamashita (23, 24) has drawn up an hypothesis for the genetics of pithiness in several species of wheat. The gene for pithiness is designated M (M for *markig*, pithy) sub-lettered according to the species in which it occurs. M_d occurs in *T. dicoccum* and *T. durum* in which, in Yamashita's varieties, it completely fills the stem with pith. M_p occurs in *T. polonicum*, in which only the uppermost internode is filled, and M_t in *T. turgidum*, the stem of which is only filled for a few centimetres below the spike. These are regarded as multiple allelomorphs. A recessive allelomorph m_{β}' occurs

in the B genom of *T. spelta*. This has been studied genetically, independently of the C genom, in 28-chromosome hybrids from the backcross *T. polonicum* × *T. spelta* F_1 × *T. polonicum*. An additional and principal gene for hollowness was found in the C genom of *T. spelta*; this has been designated O_D, and it has been shown to produce the hexaploid wheat type of hollowness.

MATERIALS AND METHODS

Parent Varieties

The hollow parent varieties of the hybrid material used in this study are named and described as follows: *T. durum* vars. Pentad, Kahla and Pelissier, and *T. turgidum* var. Alaska. In all these varieties, the hollow portion of the stem extends from node to node, except for a few mm. just above each node, where the pith occupies the full inner diameter of the stem. In the uppermost internode, the cavity disappears due to the contraction of the stem diameter toward the spike; the distance from the spike at which the cavity can no longer be detected is variable. The periphery of the cavity or inner wall surface is smooth and free from striations, fractures, or septa, except perhaps in the lowest aerial internode, which has more the characteristics of a crown than of a culm internode. In green material, the inner wall of pithy tissue appears to be a few (probably two or three) cells in thickness. It is colourless, and thus distinct from the chlorogenous cortical cells surrounding the vascular bundles. In ripened material, lacking chlorophyll, this distinction does not appear.

T. durum var. Golden Ball was the solid parent used in crosses with all 4 of the above hollow varieties. Stems of plants of this variety grown in the greenhouse have been studied with some care. It was observed that a cavity occurred in the first internode below the spike. This was located above the node and was narrow or filiform, tapering up into the pith to various distances. A more pronounced cavity frequently was seen in the second internode below the spike, in a position analogous to that of the first described. Similar cavities were sometimes noted in the third internode from the spike. The surface of the pith surrounding these cavities was shredded and rough; the cavities were sometimes interrupted by septa.

Further observations were made on material from plots of Golden Ball grown in the field nursery in the summer of 1938. In this, cavity development was less marked than in the greenhouse material. There was variation in the amount of cavity development both within plants and between plots. To attempt to trace the source of the variation within plants, the results of the examination of the primary culms were separated from bulk and considered in comparison with the results of the examination of the bulked lot of culms. No significant difference could be discerned in the extent and type of cavity development between these 2 groups. Between material from the 4 different plots, scattered throughout the nursery, considerable variation occurred in percentages of culms having cavities. Of all the culms from the 4 plots, about 61% had no cavities of the type being studied at all; 25% had cavities in the second internode below the spike only; the remainder had cavities in other internodes or combinations of internodes.

Cavities of a different character also occur at the top of each culm internode, just below the node. These occur as a uniform part of the morphology and in contrast to the others, are most pronounced in the lower internodes, becoming smaller proceeding up the culm, until reduced to the approximate size of a drop of water. They taper downward into the pith, and have smooth uniform walls. These latter cavities as found in Golden Ball are regarded here as the vestige or remnant of the cavity as found in hollow varieties. Beyond these observations, they have received no further attention in this study.

Hybrid Populations

The F_2 seed of the first 3 crosses listed below was contributed by the Field Husbandry Department, University of Saskatchewan. The fourth cross was made by the author in the summer of 1937. Hybrid populations of the following parentages and generations were studied:

1. Pentad × Golden Ball; F_2 and F_3.
2. Kahla × Golden Ball; F_2 and F_3.
3. Alaska × Golden Ball; F_2 and F_3.
4. Pelissier × Golden Ball; F_1 and F_2.

Approximately 80 F_2 plants of each of the first 3 crosses were grown in the greenhouse in the fall and winter of 1937. The mature plants were classified and their phenotypes recorded according to their stem cavities. Progenies of all F_2 plants which produced seed in the greenhouse were grown in the field in the summer of 1938.

F_2 plants of the same 3 crosses, grown from the same seed supply as the greenhouse F_2, were grown in the field in the summer of 1938; observations on these plants supplemented those made on the greenhouse F_2.

The author crossed Golden Ball and Pelissier in the summer of 1937; the F_1 was grown in the greenhouse in the fall and winter of 1937 and the F_2 in the field in the summer of 1938.

Soil and Climatic Conditions

The soil in the nursery is heavy, of a silty clay loam texture. Though giving the impression of uniformity on the surface, there are abrupt subsoil variations which make the soil variability actually rather high. During 1938, the total precipitation for the months April to August inclusive was 7.60 inches, which was 1.32 inches below normal for that period. This deficiency was not enough to affect the vigour of the plant growth seriously. The seed was sown in the nursery May 16–17, in 5-foot rows spaced 1 foot apart. No particular attention was given to the spacing of seed within the rows; in F_3 families, where the amount of seed produced by the parent F_2 plants was small in some instances, there was doubtless some variation in seed spacing. The Kemp V-belt nursery seeder was used.

Methods of Classification

Determination of Phenotype.—It proved desirable in the initial stages of this study to determine the phenotypes of plants by splitting the culms lengthwise throughout the entire length. The resulting longitudinal

section affords the observer a complete impression of the phenotype at a glance. About 800 F_2 and 1640 F_3 plants were studied in this manner, on a basis of slightly less than 3 culms per plant. In the later stages of the work, when the trend of the genetic results was becoming well established, progress was accelerated by merely cross-sectioning a culm of each plant at a certain place. Observations had shown that the presence of genetic factors for pithiness was almost certain to be shown by the presence of pith in the lower internodes of the plant. Therefore, 1 or 2 cross-sections through the fourth or fifth internode, counting down from the spike, served to separate hollow segregates from others. This permitted a crude classification which proved adequate for the purpose of checking F_2 classification by breeding behaviour in the F_3.

Notation and Recording.—The F_2 plants grown in the greenhouse were placed in 3 classes: *Solid*, plants having phenotypes closely similar to that of the solid parent; *Intermediate*, pithy plants having a greater degree of cavity development than the solid parent; *Hollow*, plants having cavities indistinguishable in character from those of the hollow parent variety. Among intermediate F_2 plants grown in the greenhouse and the field it was observed that considerable variation occurred in the amount of cavity expression. This variation was of such a nature that it made the distinction between "solid" and "intermediate" segregates sometimes rather arbitrary. However, the nature of the intermediate condition was such that it was never confused with the hollow phenotype.

In order to avoid the loss of information that might prove of value in the genetic analysis, considerable effort was put into recording the cavity expression in intermediate material in detail. In the initial stages of the study of the field-grown material, a method was developed for recording the condition of each internode as to its cavity development. Eventually, even this was refined to record the information for each separate culm of a plant, since the field material, unlike the greenhouse material, showed variation within as well as between plants. The amount of cavity expression in a culm is obviously difficult to measure and record quantitatively. It seemed however that the number of internodes per culm having cavity development was positively correlated with the total amount of cavity development. The number of consecutive internodes having cavities and the position of such internodes in the stem was therefore used as a criterion of classification. (Cavities commonly occur in a series of consecutive internodes.) The criterion of classification was designated by the position of the internodes involved, numbering down from the spike, for example, No. 1, 2, 3, or No. 2, 3, 4. A plant, though capable of varying phenotypically in its various culms, must obviously be assigned to a genetic class as a unit. The maximum cavity expression in any culm of a plant was taken as the typical culm. This was justified to the extent that on an average, 50% of the culms of the plants in any class conformed to the classification; the remainder tended to approach this maximum as a mode. Since the information obtained by this detailed work contributed nothing to the factorial interpretation of the results, and seemed not of very great or any practical significance, the results are not being dealt with extensively.

RESULTS

The Study of the F_1

F_1 plants were available for study only in the case of Golden Ball × Pelissier. The intermediate phenotype as observed in 9 F_1 plants grown in the greenhouse was as follows: cavities occurred in the first, second and third internodes below the spike. These extended up from the lower internodes and merged into the pith, terminating about one-third to three-fourths the distance up the internode. The cavities resembled those observed in the parent variety Golden Ball in that they were tapering, with rough and fractured pithy walls, and with the cross-sectional outline irregular instead of circular. Beneath each stem node, smooth-walled cavities analogous to those already described for Golden Ball were present. These conditions differed from those of the solid parent in being more constant and more pronounced, the diameters and lengths of the cavities in the F_1 plants being greater. In the greenhouse material, the condition was more consistent among F_1 plants than among intermediate F_2 plants. In F_1 plants grown in the field, cavities were consistently noted only in the uppermost internodes, and only occasionally in the second internodes.

The Study of the F_2

Genetic Results.—The results obtained from the first tentative phenotypic classification of the F_2 are presented in Table 1. In Table 2 the classification as corrected by genetic analysis in the F_3 is presented, along with the amount of error in the classification of solid and intermediate segregates by their phenotypes. The P values of the χ^2 tests for goodness of fit vindicate the monofactorial hypothesis in each case. In the study of the F_2 populations grown in the field (Table 3), satisfactory fits to the single factor hypothesis were obtained in all cases except that of Golden Ball × Pentad. The behaviour in this cross differs from that of the greenhouse material of the same origin and from that of the F_3 families of heterozygous plants. Table 3 also shows the different frequencies of occurrence of various intermediate types among F_2 hybrid populations of different origin.

Phenotypes in the F_2.—(1) Solid segregates. Data from progeny tests of F_2 phenotypically solid plants showed that a plant resembling the pithy parent might be either homozygous or heterozygous (Tables 1 and 2). There is therefore a possibility of error in attempting to classify these plants genetically by their appearance. The proportion of heterozygous plants which may appear solid varies according to the environmental conditions under which the populations were grown (compare solid classes, Tables 1 and 3) and according to the parentage (Table 3).

TABLE 1.—CLASSIFICATION OF GREENHOUSE F_2 BASED ON PHENOTYPE

Parentage	Solid	Inter-mediate	Solid plus Inter.	Hollow	χ^2	P value
Golden Ball × Pentad						
Observed	11	55	66.00	15.00	1.56	.20–.30
Expected (3 : 1)			60.75	20.25		
Golden Ball × Alaska						
Observed	17	42	59.00	26.00	1.49	.20–.30
Expected (3 : 1)			63.75	21.25		
Golden Ball × Kahla						
Observed	21	29	50.00	22.00	1.20	.20–.30
Expected (3 : 1)			54.00	18.00		

TABLE 2.—CLASSIFICATION OF GREENHOUSE F_2 AS CORRECTED BY GENETIC ANALYSIS

Parentage	Solid		Intermed.		Corrected ratio (1 : 2 : 1)	χ^2	P value
	Non-seg.	Seg.	Non-seg.	Seg.			
Golden Ball × Pentad							
Observed	7	4	14	36	21.00 : 40.00 : 14.00	1.64	.30–.50
Expected					18.75 : 37.50 : 18.75		
Golden Ball × Alaska							
Observed	11	6	4	37	15.00 : 43.00 : 25.00	2.52	.20–.30
Expected					20.75 : 41.50 : 20.75		
Golden Ball × Kahla							
Observed	12	8	5	21	17.00 : 29.00 : 21.00	1.69	.30–.50
Expected					16.75 : 33.50 : 16.75		

TABLE 3.—CLASSIFICATION OF FIELD F_2, INCLUDING VARIOUS CATEGORIES OF INTERMEDIATE PLANTS

Parentage	Solid	Intermediate. Plants with cavities in internodes as numbered								Solid plus Intermediate	Hollow	χ^2	P Value
		No. 1, 2 3 & 4; No. 1, 2, 3, 4 & 5	No. 1, 2 & 3	No. 2 & 3	No. 2	No. 3	No. 1 & 2	No. 1	Total				
Golden Ball × Pentad													
Observed	63	0	5	0	5	0	30	25	65	128.0	28.0	4.37	.02–.05
Expected										117.0	39.0		
Golden Ball × Alaska													
Observed	56	3	1	2	17	1	0	0	24	80.0	26.0	—	—
Expected										79.5	26.5		
Golden Ball × Kahla													
Observed	102	0	0	0	12	0	12	7	31	133.0	37.0	0.95	.30–.50
Expected										127.5	42.5		
Golden Ball × Pelissier													
Observed	32	7	33	4	0	1	20	9	74	106.0	33.0	0.12	.70–.80
Expected										104.2	34.8		

(2) Intermediate segregates. There was a tendency to place some plants in this class which later proved to be homozygous for pithiness. Some homozygous solid segregates may then have a more pronounced cavity development than the parental type. The F_2 intermediate plants grown both in the greenhouse and the field differed conspicuously from the intermediate F_1 plants in their range of variation of cavity development, the F_1 plants, as stated, having been fairly uniform. The relative uniformity of culms within plants grown in the greenhouse suggested a genetic basis for this variation. On the other hand, the variation within intermediate plants from the field gave the impression that seasonal changes in ecological conditions were responsible for the variations, since different culms of any plant and different plants are not in the same developmental stage simultaneously in all cases. The fact however that the majority of culms of plants in a given class conform to one type, and that evidence has been obtained from the F_3 substantiating the heredity hypothesis, indicates that some of the variation in the amount of pith present is hereditary.

Detailed studies of the phenotypes of F_2 plants of 4 different parental origins revealed that not only the frequency of occurrence but the degree and character of the intermediate phenotypes varied between different crosses. In F_2 populations in which cavity development occurred most frequently, there was a tendency for cavities to be present in more internodes per culm than in those in which cavity development occurred less frequently. In the F_2 of Golden Ball × Pelissier, for instance, in which the number of plants classified as intermediate closely approached the genetically expected number (1 : 2 : 1 ratio), there is a high percentage of plants having a combination of cavities in internodes No. 1, 2, and 3, and in internodes No. 1, 2, 3, and 4. In the Golden Ball × Alaska F_2 , in which the intermediate class was only one-half as large as expected, most of the cavities occurred in internode No. 2 only, and it is obvious that judgment must be used in separating these from the solid class. Again, in the Golden Ball × Pentad F_2, in which the observed number of intermediate segregates approached the expected, the combinations of internodes having cavities differ from those observed in Golden Ball × Pelissier.

(3) Hollow segregates. These appeared to be exactly similar to the hollow parent variety in respect to cavity development. There was no error in the classification of these plants; all were true breeding in genetic tests.

The Study of the F_3

The results of the study of 119 segregating F_3 families are summarized in Table 4. The values of χ^2 given in the first three tiers of the table are the sums of the values of χ^2 worked out for the ratios observed in each F_3 family individually. Only the χ^2 values for the five lines which did not show a satisfactory statistical fit to the expected ratios were kept separate from these totals. Excepting these 5, all the values of P indicate a high probability that the monofactorial hypothesis is valid. Especially in the case of Golden Ball × Alaska and of Golden Ball × Kahla, the F_3 progenies

TABLE 4.—STATISTICAL SUMMARY OF F_3 RESULTS

Origin of F_3 lines	No. of lines	Total plants	Observed ratio (bulk)		χ^2 Sum of values for all lines*	P Value
			Solid plus Inter.	Hollow		
Golden Ball × Pentad						
Progeny of intermediate heterozygous F_2 plants	35	698	518	180	23.852	.80
Progeny of solid heterozygous plants	4	92	76	16	5.069	.20–.30
Golden Ball × Kahla						
Progeny of intermediate heterozygous F_2 plants	19	342	264	78	9.090	.95–.98
Progeny of solid heterozygous F_2 plants	8	158	118	40	2.912	.90–.95
Golden Ball × Alaska						
Progeny of intermediate heterozygous F_2 plants	30	589	434	155	25.953	.50–.70
Progeny of solid heterozygous F_2 plants	8	139	96	43	5.060	.70–.80
Individual F_3 lines with large deviations from expected ratios						
Golden Ball × Pentad	1	13	6	7	4.333	.02–.05
Golden Ball × Kahla	1	20	11	9	4.267	.02–.05
Golden Ball × Kahla	1	15	7	8	6.422	.01–.02
Golden Ball × Alaska	1	18	8	10	8.963	.01–
Golden Ball × Alaska	1	24	13	11	5.555	.01–.02

* Includes all values for individual lines ($n = 1$) for which the P value exceeds 0.05 (Fisher's Table of χ^2)

of solid F_2 plants which proved to be heterozygous fitted the expected ratio as well as those of the intermediate F_2 plants. It will be understood that where the 5% point in Fisher's table of χ^2 is used, values of χ^2 will be expected to exceed 3.841, where $n = 1$, in 5% of cases, where the deviation from the expected ratio is due to chance alone. Formally, with 119 lines, about 6 such deviants would be expected; actually there are 5. The 5 deviants do not therefore disturb the 3 : 1 hypothesis.

The results of the study of the variation of pith content among F_3 families in which no hollow segregates appeared to not seem to be very susceptible to genetic interpretation. Since some genetically solid plants were erroneously classified as "intermediate" in the F_2, there would seem to be a wider variation among the segregates than among the Golden Ball parental population. Since the most detailed method of recording is still too crude to show this by a study of the records taken, the range of variation probably does not overlap that of the heterozygous plants to a very great degree.

The genetic sources of variability in heterozygous F_2 plants were only studied in the F_3 in a very broad way. In the F_3 of Golden Ball × Kahla, the intermediate segregates from 6 families of intermediate heterozygous

F_2 plants were classified; 32% of the 122 plants were classified as intermediate. In the progenies of 6 solid heterozygous plants of the same origin, only 16% of 102 plants were classified as intermediate. In the F_3 of Golden Ball × Alaska, the corresponding percentages were 50 and 34. These observations lead to the idea that there are probably genetic factors operating to modify the degree of pithiness, especially in the heterozygous state. A closer study of the finer gradations of expression would likely bear this out still further.

DISCUSSION

It would seem that homozygous or even heterozygous pithy plants would have their stems completely filled with pith, were it not for the fact that in some cases, especially in the upper and later developing internodes, the growth rate of the stem wall exceeds the growth rate of the pith within. The evidence indicates that both environmental and genetic factors may cause this differential growth. In any case, the result is a cavity left by the fracture of the structure of the pithy tissue, which is not a vestige of the stem cavity as found in hollow varieties. In plants heterozygous for the gene for pithiness, the tendency for such a fracture to take place is more pronounced.

There are several factors which tend to make a study of the reported investigations of this character confusing. Most if not all the workers who have published seem to have relied upon a cross-section or series of cross-sections at arbitrary points for their method of examination. This may have produced wrong impressions. Again, it is necessary to consider the likelihood that in referring to pithy stems, not all the investigators have had the same thing in mind. Watkins (22) for instance, states that all forms of *T. turgidum* are solid or solid at the top with "a small lumen in the lower parts". Needless to state, this is not the same as the point of view taken with respect to the *turgidum* variety Alaska in the present work. In Yamashita's genetic hypothesis, the gene M_t is said to fill the stem with pith in *T. turgidum* var. *nigrobarbatum* Korn. for a short distance below the spike. His photographs show pithiness to a point between 10 and 15 cm. below the spike; the remainder is as hollow as any other tetraploid variety. From Yamashita's photographs, and from the writer's own few observations, there is a suspicion that the same applies to *T. polonicum*. The genes M_t, M_p, and M_d are regarded by Yamashita as multiple allelomorphs, but since there is no doubt that Yamashita's *T. durum* and *T. dicoccum* are really solid, the correctness of the gene M_d in this allelomorphic series becomes questionable. In *vulgare*-like derivatives of *T. vulgare* × *T. durum* (solid) crosses, the pithy condition, if present, is subject to even more variation due to environment than that described for the heterozygous plants studied in this work. Kemp and Platt (10) have described the sensitivity of this character in such types of wheat; this seems great enough to have a bearing on the earlier conflicting reports of the results of interspecific crosses. Further, although the species involved often belonged to numerically different chromosome groups, the results were often interpreted in terms of simple genetic ratios; such interpretations might have been legitimate if the genes governing the character concerned were confined to homologous chromosomes in homologous genoms, but cytogenetic

work has indicated that this is not the case. It is rather significant therefore that in later studies, particularly cytological ones, simple factorial interpretations have not been offered.

Five previous instances of studies of pithiness in crosses between pithy and hollow tetraploid wheats have been reported. In the 4 cases presented by Engledow and Hutchinson (3), the genetic results have been interpreted in the same way as those of the present study, but if, as suggested, the pith as found in their varieties of *T. turgidum*, *T. polonicum*, and *T. durum* is morphologically different, their results may not be strictly comparable to those of the present investigations. Goytia y Angulo, who definitely seems to have used a solid parent variety, suspected that two pairs of factors were involved; failure to appreciate the fact that homozygous solid plants may contain small cavities may have given him incorrect impressions.

In genetic and cytogenetic studies involving parents of different chromosome number, the results of the investigations of pithiness have not been consistent. Besides the possible influences of environmental factors, these differences are correlated with the different proportions of segregates belonging to the increase and decrease chromosome groups in the F_2. In the progeny of F_1 hybrids of *T. durum* or *T. dicoccum* and *T. vulgare* such as those studied by Kihara and by Thompson and Hollingshead, it has been customary to find a great deficiency of F_2 plants having the theoretically expected intermediate chromosome numbers, and an unproportionally large number reverting to the chromosome condition of one parent or the other. The decrease has been larger than the increase group. Because of the correlation of chromosome and morphological conditions, the tetraploid morphology, including pithiness, appeared dominant. But in Matsumura's *T. polonicum* × *T. spelta* hybrids, the situation was entirely different. The increase group was the larger, and hence the hexaploid morphology and pith content appeared dominant.

According to the factorial hypothesis of Yamashita, based on his own studies and supported by some other evidence, the hexaploid species may have 2 genes for hollowness. The gene m_B'—recessive and allelomorphic to the various M genes, is located in the B genom, while O_D, which seems to make the distinction between the hexaploid and tetraploid type of hollowness, is in the C genom. Apparently m_B' has not been recognized by Matsumura in material of similar parentage, nor has Yamashita as yet demonstrated its existence in *T. vulgare* as studied in *T. vulgare* × *T. durum*. Certainly however the existence of the gene O_D is well established by the observation of F_1 plants, the study of trisomic plants and other evidence. It seems quite probable that a similar gene may be present in *T. vulgare* as well as *T. spelta*. From the ordinary mechanism of meiosis in pentaploids, in which it appears that the chromosomes of the C genom do not mate with those of the A or B genoms, it would seem impossible to replace O_D with a gene for pithiness; therefore it would be impossible to obtain a *vulgare*-type derivative by hybridization, homozygous for pithiness in both factor pairs. The only possibility of accomplishing complete polymeric homozygosity would be in a mechanism similar to that described by Huskins (5) to explain the appearance of fatuoid oats in *Avena sativa* L. The theory is that segmental interchange between semi-

homologous chromosomes from different genoms has resulted in the replacement of the *sativa* gene complex with the fatuoid complex, to which the *sativa* complex is normally epistatic. In a solid *vulgare* type derivative of *T. vulgare* × *T. durum*, the gene M_d for pithiness would have to be duplicated in the C genom by an analogous process. Recently the occurrence of such meiotic irregularities in varieties of hexaploid wheats, especially those of recent hybrid origin, has received increasing attention. Love (12) has reported the frequency of trivalents and other abnormalities at meiosis in hybrids of various origins. These are fairly numerous, and are regarded as evidence of rearrangements of chromosome segments.

At present, nothing exact seems to be known about the specific environmental influences which affect cavity expression. For selection work this could be a matter of importance, for, as work with the field F_2 has shown, a large number of heterozygous plants may be solid. Solid and intermediate phenotypes will probably always overlap at least to some extent under all conditions, but a more careful study of this particular point might indicate what environmental conditions provide the maximum distinction between the two.[3]

SUMMARY

The results of the present investigations strongly indicate that the inheritance of solid straw as found in *T. durum* var. Golden Ball is unifactorial, when Golden Ball is crossed with other *durum* varieties and varieties of *T. turgidum*. The solid character is partially dominant, and the distinction between solid and intermediate genotypes is not always possible, but the recessive hollow class is phenotypically readily distinguishable.

It has been shown that the solid heterozygous plants and the intermediate heterozygous plants segregate in the same way with respect to the proportion of hollow plants in the progeny, but that the solid heterozygotes themselves produce more solid plants than the intermediate heterozygotes. This indicates a partial genetic basis for the variation in cavity expression observed. Environmental influences add to this variability.

The association of the solid character with any undesirable grain characteristics has not been investigated in this work, but barring such a possibility, the results indicate that the production of a high quality solid stemmed *durum* variety would be relatively simple. Research in the literature on the subject indicates that the production of a solid stemmed *vulgare* type wheat using *durum* parent material as a source of pithiness would be a major problem in plant breeding.

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[3] See PLATT, A. W., the influence of some environmental factors on the expression of the solid stem character in certain wheat varieties. Sci. Agric. 22; 139-151, 1941.

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THE SOILS OF EASTERN ONTARIO

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Eastern Ontario, in this report, is considered to be the part east of Kingston and the Ottawa Valley as far up as Petawawa. It comprises about 3,500,000 acres. In a previous article the physiography of this area was outlined (1), and the purpose of this article is to present a general description of the soils.

SOIL FORMING INFLUENCES

Climate

The climate in this eastern part is more sevère than in the rest of Southern Ontario which is cleared for agriculture (7). The winters are colder and longer. However, because of lower altitude and greater distance from the lakes, the summers are as warm as in a broad strip running southwestward to Lake Huron. Within the area summer temperatures are fairly uniform but in winter the temperature drops rapidly from Kingston northward so that in January Renfrew is eight degrees colder than Kingston. This variation has a marked influence on vegetation and soil.

The rainfall is generally about 34 inches, with the Renfrew vicinity receiving several inches less and the eastern end having the heaviest fall of nearly 38 inches annually.

Natural Vegetation

The natural vegetation is of particular interest in Eastern Ontario because here more than in other parts of agricultural Ontario there are definite soil differences due to changes in the type of forest. The outstanding case in point is the contrast between the clay soil of Renfrew County and that in the clay flats bordering the Carp River in northwest Carleton. Most of the former is an acid podsol clay with a thin surface layer and an ashy, grey, leached horizon beneath. It was developed under spruce and pine. In the Carp Valley and in Dundas County farther south the soil has a dark surface layer 3 to 6 inches in depth; it is neutral and lacks the well-developed leached layer. Its vegetation was a mixture of elm, ash and soft maple with here and there some swamp white oak. Now there is a conspicuous contrast in roadside vegetation: in Renfrew, silver cinquefoil abounds while the darker, moister soil has a thick bluegrass sod.

Figure 1 is a chart of the various forest associations. In addition to the two already mentioned, a third is found on the clay soil east of Ottawa and consists of white pine and hardwoods. Sugar maple and elm are the dominant hardwoods. The pines on this heavy soil seldom grow to be very large, indicating that conditions are not ideal for the species. Much the same type of forest grew on the shaly till soils north of Russell Village. Under this association the soil is less strongly podsolized than in Renfrew County. On the clay soil of Leeds County and Wolfe Island, elms, ash,

hard and soft maples, swamp white oak and hickory are seen. About half of this soil is acid, with a grey leached horizon; the remaining half, in lower sites, is quite immature like the Carp Valley and Dundas County counterpart.

Originally some of the best stands of pine in the province were located on the sandy soils of the Ottawa Valley. White and red pines occupied the better sands together with a sprinkling of maples, yellow and white birch, balsam fir and cedar. Brake ferns are now very common in clearings. Of



FIGURE 1. Forest Associations of Eastern Ontario.

course these forests have long since been cut off and much of the land is now barren. Occasionally there are blow-outs proving the error of deforesting such soil, if proof be needed.

While white pine occupies the better sandy loams, red pine is found on somewhat coarser sands and jack pine on the coarsest and driest of all. Around Petawawa and other places in Renfrew County there are good stands of jack pine. On these dry plains there is ground cover of club mosses blueberries and Labrador tea.

There is a mixture of evergreens and hardwoods, the typical "L 4" association of Halliday (4), on the shallow soil over the hard, knobby Laurentian rocks. This association flanks the area on the west and there are separate patches in Renfrew and Carleton also. White and red pine, sugar maple, beech, hemlock, balsam fir, basswood, red oak and birches are typical.

Forests consisting mostly of sugar maple and beech are still common in Glengarry on the rolling stony loams, and while white cedar thrives on the associated wet soils, white and red cedar characterize the shallow limestone soil along with a roadside flora of stonecrop, blueweed and mullein.

Geology

In view of the complete physiographic account given in a former article (1), only the main points will be reviewed here. Since all the area was submerged under the sea following the melting of the last ice-sheet, the topography is all more or less planed, either by wave action on the hills or the deposition of sand or clay in the hollows. The hills of glacial till, and the shallower tills as well, consist mostly of broken rock and rock flour from the underlying formation. Also the water-laid sediments in the vicinity of the limestone tills or the red or gray shale tills are directly affected by the admixture of local material. However, in the case of most of the sand, silt or clay, the material in the beds came from outside sources, that is from the surrounding Laurentian highlands. Our foremost interest is in the clays and the differences in them, and the resultant soil characteristics will be pointed out in due course.

In point of age, the youngest soils of Southern Ontario are located in the eastern counties. All Ontario soils are relatively young, as the presence of so much high-lime soil would indicate. The actual lengths of time that weathering has operated following the recession of the glacier from the various parts of the province has been estimated by geologists and their figures are of interest here (3). The first land was uncovered around Shelburne in Grey and Dufferin Counties some 30,000 to 50,000 years ago. All of Southwestern Ontario, excepting a narrow strip along Georgian Bay and Lake Huron, was free of ice and of glacial waters by 20,000 to 25,000 years ago. The area north of Lake Ontario was partly uncovered at this time and it emerged piece by piece until the last water receded about 8,000 to 10,000 years ago. Probably about 4,000 years then elapsed before the land of Eastern Ontario rose above sea-level.

Younger, more immature soil profiles tend to be shallower, less acid, less heavily leached and higher in humus than the older ones. In Ontario there is not the striking contrast in soil profiles due to varying age that there is, for example, between the soil on Wisconsin and on older drifts in Southern Ohio. However, there are discernible differences between profiles in Southwestern Ontario and Central or Eastern Ontario.

It is notable also that in younger soils the influence of geological material is more manifest. The strong correlation between parent material and the chemical and some of the physical properties of soils was well illustrated in Southwestern and Central Ontario (6, 2), further evidence being provided by the soils that are about to be described.

Pedology

According to Morwick, Eastern Ontario is in the podsol zone (5), lying near the southern border of it. Proof of this lies in the extensive occurrence of grey-brown podsolic soils along with the podsols and in the weak development of the podsols themselves. Usually there is only a thin, grey layer in well-drained situations.

Of even greater practical importance is the fact that a high proportion of Eastern Ontario soils fall into the intrazonal category because of poor drainage. The distribution of these will be shown later in the section on drainage.

While the climatic, botanical and especially the geological influences are stressed in this report, the classification into types is based on the soil profile which embodies all the contributing influences. Here, as in South-Central Ontario (2), the many types were rationalized into a few divisions, those having similar profiles, characteristics and uses being grouped together. The areas so mapped of course include minor associated types.

NATURAL LAND TYPES

1. *Shallow Limestone Plains*

The most extensive type to be described is the shallow soil on the level dolomite or limestone. The main tract will be seen from Figure 2 to occupy part of Leeds, Grenville, Carleton and Lanark Counties, with smaller outliers in separate locations. It makes up about one-fifth of the total area, or a little over 1100 square miles.

Most of this soil consists of a few inches of stony loam over sandy dolomite while the rest of it overlies limestone or sandstone. The sandstone area, which is in Nepean Township not far from Ottawa, is acid in reaction instead of being near-neutral as in other areas. Doubtless there are other differences due to bedrock, but the dominant quality is drouthiness and shallowness, so no further distinction has been made on this basis. Here and there one finds some water-laid loam over the bedrock and this is usually associated with better soil. On higher sites there are some gravelly ridges while swamps occupy the depressions.

The main use of this land is for pasture. Oats, alfalfa, or sweet clover, and silage corn are grown on any patches of soil 10 inches or more in depth wherever such is found. The drouthiness of the normal soil prohibits economical response to expensive treatment so no commercial fertilizer is advised. The deeper patches produce some very good crops except in dry seasons and therefore may warrant special fertilization. For these no general recommendations can be given because of variability; however, a test can be obtained at any time by sending a sample to the nearest soils laboratory.

Milk and hogs are the main products of farms on this type of soil. In addition, the farmer may supplement his income with the sale of maple syrup, turkeys or cordwood. It is at best a marginal soil, yielding only a subsistence. This has led to some farm abandonment or an increase in size of farms and it seems likely that this trend will continue. Possibly



FIGURE 2. Natural Land Types in Eastern Ontario.

the cost of public services will force complete abandonment from some of the poorer tracts. Unfortunately, this adjustment will entail a great deal of disappointment to those concerned.

2. *Moderately Shallow, Stony Loam*

The next of the types represents an intermediate condition between the shallow and the deep limestone till soils. It is a low-lying, gently undulating, stony loam. Some ridges of deeper, well-drained soil are associated and also considerable marshy land and bog. In all, there are about 336 square miles so classified, most of which is in southern Dundas and Stormont Counties and Kenyon Township in Glengarry. Smaller tracts, such as the one west of Perth, are also shown on the map.

This type can hardly be described by reference to certain profile characteristics because of its variability, though it differs from the deeper limestone till soils in having a darker surface layer and a subsoil that is more mottled with rusty yellow or brown. Stoniness has already been

mentioned as a characteristic and this will bear repetition. Perhaps, for obvious practical reasons, less labour has been put into clearing the stones off this than off the better soil. At any rate it is now more generally stony; blocks of local limestone and hardheads from the Precambrian litter the surface, keeping much of it in rough pasture.

From a chemical standpoint this soil is as good or better than the deeper limestone soils. A neutral reaction, a good supply of calcium and magnesium, and low phosphorus and potash content, is normally found, as is the case in its deeper counterpart. This soil is higher in humus. Here again the advisability of applying chemical fertilizer is contingent upon drainage conditions, depth and stoniness. This means that those fields which are most improved are the only ones that will be likely to repay the cost of special fertilization.

Besides pasture the chief crops are hay, oats and corn. Alfalfa and sweet clover are confined to the higher sites, timothy and alsike filling in on the lower land. Corn also does poorly on any but the better-drained locations. Buckwheat is a common crop on the later fields.

3. *Limestone Till*

In South-Central Ontario the most extensive natural land type is that developed on the limestone tills. Somewhat similar soil in Eastern Ontario covers about 10% of the area, or 528 square miles. Glengarry and Carleton contain the highest proportion while it is scattered over Stormont, Dundas, Grenville and in lesser amounts in all other counties. The topography is generally rolling though seldom, if ever, too steep to cultivate, as is often the case in Peterborough and Northumberland. On the other hand, much more of it is unplowed, due to excessive stoniness, than in Central Ontario.

The normal profile (Figure 3) has a 2- to 4-inch surface layer of dark brown, granular, stony loam. The leached horizon is faintly developed and is usually less than 3 inches in thickness. Under this is a coffee-brown "B" layer that overlies the grey, stony, loamy till at a depth that varies all the way from 10 to 30 inches from the surface.

The chemical attributes are a neutral or slightly acid reaction, plenty of lime, a medium humus content and low potash. The available phosphorus content must also be classed as low since it responds to phosphatic fertilizer, though it is better supplied than most soils in the province. This is particularly true of this soil in Glengarry and Stormont, where it contains a higher proportion of Trenton limestone. According to the tests a fertilizer containing phosphorus and plenty of potash, such as an 0-12-20, should form the basis of a fertilizing program on this soil.

It must be rated as first-class land, in spite of some excessive stoniness and some associated wet land. Alfalfa, oats, barley and silage corn, the staple crops on the dairy farms, are all well adapted. Another point of importance to dairy farming is that the porous nature of the soil and substrata pre-determines a good supply of well-water, a utility that is sometimes lacking on a clay plain.

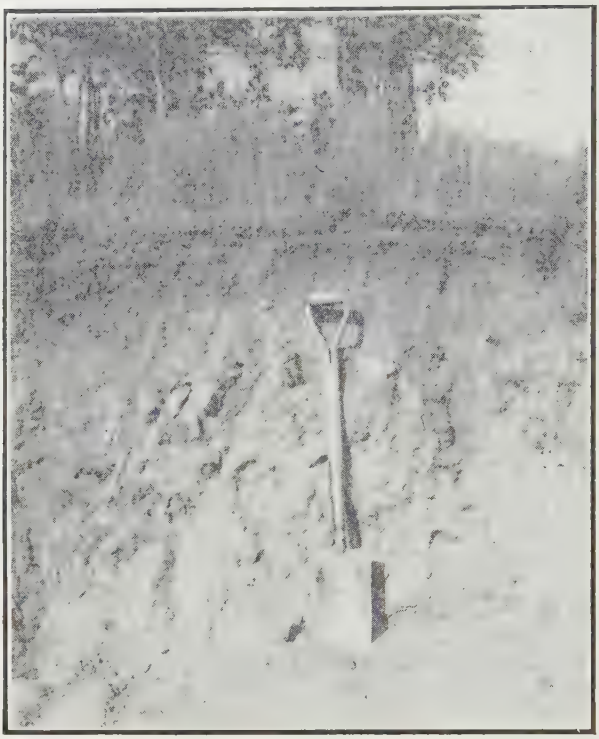


FIGURE 3. Profile of well-drained Soil Developed in Limestone Till, taken near North Gower, Carleton County.

4. *Shaly Loams*

The least extensive of the acid, clay loams is that developed on the shaly till in Russell County around Vars, north of Russell Village and in the vicinity of Ottawa, in all covering about 50 square miles. It is similar to the shaly soils of Peel and Halton Counties (2), although the distinctive, buff-coloured, A_2 horizon is not so well developed. As in Peel and Halton there are both grey and red soils, due to Utica and Medina shale respectively.

Stoniness is not a serious limitation, as with the other till soils, but otherwise the physical properties are not quite so desirable. It is not so easy to cultivate, having more of a tendency to clod and bake. Nevertheless, it is a very good soil.

Chemical tests of samples from this type give pH values near 5.9, medium soluble calcium, very low phosphorus and relatively high potash levels. A composite sample made up of 11 typical samples contained 2.5% of humus. From this evidence it is apparent that stress should be placed on phosphates and organic matter in a fertility programme.

An interesting crop adaptation on this type is found with alfalfa, and here it is quite conspicuous because this legume does not grow on the surrounding soils. It is our observation that alfalfa invariably thrives on soils derived from shale, even though these are always acid. One can only speculate as to the cause of this; perhaps it is due to the high potash content.

5. *Acid Clays (A) Renfrew)*

This type occurs in Renfrew County and in adjacent parts of Lanark and Carleton, as shown in Figure 2; also in Leeds County and on Wolfe Island. It is quite extensive, occupying about 384 square miles or 7% of the total measured area. This is nearly a quarter of a million acres. The association consists of strips or patches of wetter, neutral, dark-surfaced, clay loam scattered throughout a main body of gray, acid clay. Some knolls are particularly "white". In the virgin state this latter soil has a very shallow surface layer under which is an ashy, gray layer of mealy, clay loam, a few inches to a foot in thickness as shown in Figure 4.

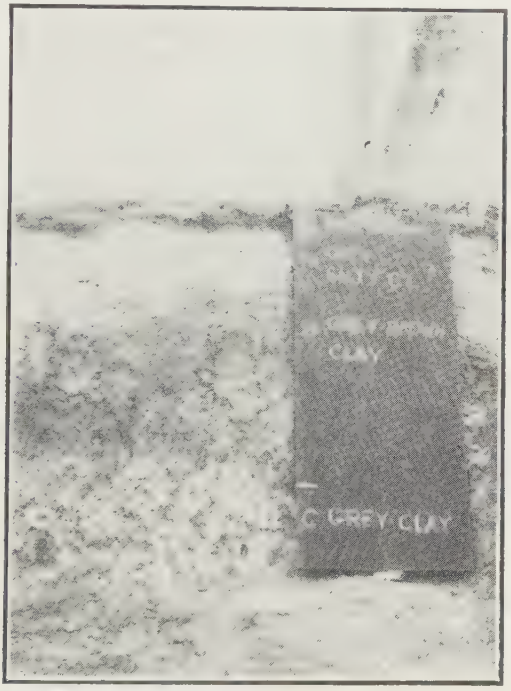


FIGURE 4. Acid Clay Loam Profile from near Admaston, Renfrew County.

For the most part it is this that forms the plowed soil in cultivated fields. The parent material is a marine clay of quite uniform, drab colour. Some of the strata will effervesce when tested with dilute hydrochloric acid, but as a rule free carbonates are wanting. Typically, this soil was developed under spruce and pine forests. Renfrew County, it is to be noted, has colder winters than the main body of Eastern Ontario. In Leeds County the natural vegetation was mixed hardwoods with some pines and the soil is not so severely leached but it is included in this category because of the practical similarity.

It is of interest to note that the Renfrew County soil constitutes as good an example of a podsol clay as the writers have seen anywhere in the province, although the Thunder Bay and Rainy River districts have not been visited. The silty clay soils between New Liskeard and Monteith

are similar in development, but in the main part of the Northern Clay Belt the soils are less mature.

With its level topography, freedom from stones and the fact that it occurs in uniform tracts, this type can be cultivated with a maximum of efficiency. It dries up early in the spring, except in hollows where drainage has not been provided. From the physical standpoint, the chief limitation is drouthiness. The weather station at Renfrew records an annual precipitation of only 26.3 inches, the lowest in the region, and a summer drouth in at least two out of five years. The low humus content of the soil (only about 2%) correlates with poor water-holding capacity. This, in the writers' opinion, is the foremost problem confronting an operator on this soil, especially if there is a high proportion of "white clay" on his farm.

In spite of the low content of organic matter and the severe leaching, the fertility is surprisingly good. Like all our soils, it has low available phosphorus, but it is higher than most in this element. The parent clays contain a good supply of phosphatic minerals. Only one other type in Eastern Ontario is as well supplied with potash and it compares favourably with the clay soils of York and Peel counties in this respect. Perhaps this is a vital factor underlying the prevalence of alfalfa in both these sections. The pH values of samples from the Renfrew soil varied from 4.6 to 6.8, with 46 samples averaging 5.9. The reactions in the Leeds County and Wolfe Island soils were a little less acid. They have, however, less soluble calcium, although both would have to be placed in a medium class. Alfalfa thrives without liming and so the feasibility of applying lime is not settled. There are no experimental results on this point.

One outstanding fact about farms on this land type is the comparative freedom from weeds. Because of this the local reputation for good, clean seed grain is steadily improving and it is to be hoped that this reputation will be safeguarded and extended by individual and community effort.

Acid Clays (B) Russell

East of Ottawa, chiefly in Russell and Prescott Counties, is found the companion type of acid clay occupying about 450 square miles. The parent material is stratified pink and grey clay of waxy consistency. Here the natural vegetation consisted of hardwoods with an admixture of white pine. Drainage conditions are poorer than in Renfrew as there is more flat land and the sub-soil is more impervious.

Here again the profile development varies from an immature half-bog type, with a highly organic layer over a mottled subsoil, to a mature podsol profile. Much of it has a grey or greenish-grey "glei" layer under a mat of peaty litter 3 or 4 inches thick. When plowed, this soil is not so grey in colour as the Renfrew type and the organic matter content is higher, averaging 2.9%. Since it is so impervious there is more run-off than usual and therefore available water is limited. This impervious subsoil also restricts root range. In view of this drouthy tendency it is fortunate that Russell and, to a greater extent, Prescott receive more rain than Renfrew and that it is more evenly distributed so as to give fewer drouths. It is a hard soil to handle because of its tendency to puddle and bake, expecially the light-coloured phases of it.

In spite of the fact that it was developed under hardwoods rather than conifers and is not so highly leached, this soil is more acid and lower in soluble calcium than the Renfrew soil. It is also quite deficient in phosphorus, so lime and phosphate are primary requirements. In available potash it is the best supplied of all Eastern Ontario soils.

The number of crops well adapted to this heavy soil is limited, which is quite a handicap. Oats, barley, alsike, red clover and timothy are the main crops grown. Corn does not thrive and alfalfa is almost entirely missing, which is in direct contrast to the Renfrew sub-type on which alfalfa grows in profusion. The two factors, acidity and poor internal drainage, are apparently responsible for the failure of alfalfa. The lack of lime could be corrected with a minimum of expense, since limestone outcrops are frequent in the area. Winter killing due to poor drainage is a more difficult problem. Red clover thrives, so the lack of alfalfa is not so serious.

Since red clover is well adapted to the heavy soil under discussion there has been some specialization in seed production. This gives a much needed cash crop to supplement the main revenue from livestock, without disorganizing the cropping system. As long as enough care is taken to keep the seed clean this area should be able to compete successfully in red clover seed production.

In past years this land was extensively planted to timothy. High prices paid for hay during the early twenties caused a rush into hay-raising. Like the alfalfa seed growers in Peel County during the same period, some operators seeded the whole farm to a single crop. The passing of the dray horse and resulting loss of a hay market has forced a reorganization of the farming system from a cash crop to general farming with a livestock specialty, albeit they are loth to abandon the hay-farming. The effect of this "fievre du foin" is still to be seen in the cropping system in Prescott, just as it is in Peel and Halton.

6. *Level, Neutral, Clay Loams*

In Figure 2 is shown a big tract of soil in Dundas County, that extends through the flats of Osgoode and North Gower Townships to join up with another tract in the Carp Valley. An area in southern Glengarry is similar enough to be placed in the same class, even though it is generally lighter in texture. The sum of these areas, along with other isolated spots of this type, amounts to about 656 square miles or 420,000 acres. This is 12% of the total. Some of the best farms of Eastern Ontario and of the province are located on this soil.

In this category have been placed all the deep clay loams and loams having thick, dark, surface layers and poor natural drainage. They are water-laid, have level topography and are stone-free. The characteristic profile is shown in Figure 5, the distinctive features being the dark surface of crumby loam or clay loam and the grey and rusty-mottled subsoil. The foremost natural limitation was poor drainage and even yet there are far too few deep, clean ditches. With the lighter loam soil, especially, drainage must be provided because it is harder to drain than the clay loam. Soil of this sort is worth considerable effort because when drained it is exceptionally productive.

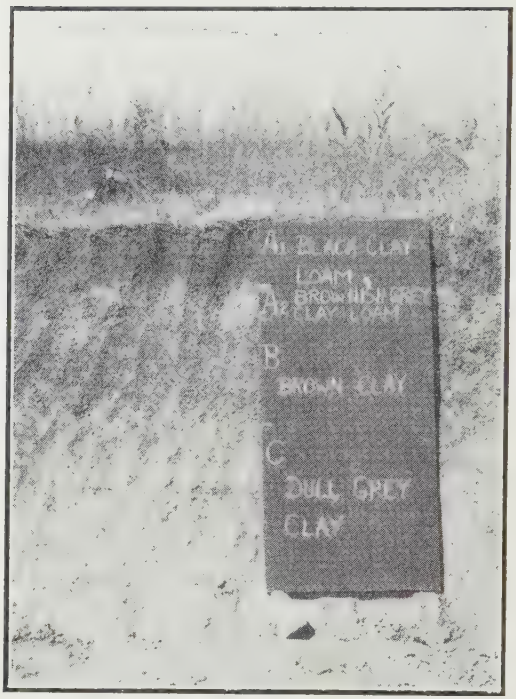


FIGURE 5. Neutral Clay Loam from near Winchester, Dundas County.

After drainage is established the most important deficiency to be considered is that of readily available phosphorus. This is not an acute deficiency by any means, in fact this clay loam is the best supplied of all Eastern Ontario soils, but phosphate gives marked benefit on clover, grain and corn. Oddly enough there is less available potash in these dark clay loams than in the acid clays with the grey, leached surface layers. The loams in this group are quite low in potash, often testing lower than 20 p.p.m. in the sodium chloride extract. This is interpreted to mean that the loams should be given potash, and even the clay loams when not recently manured might respond well enough to justify the use of potash as well as phosphorus.

This is the best grain-growing soil in the area and fine crops of alfalfa, red clover and fodder corn are grown too. In the Carp Valley a system of grain-farming has been widely adopted while in Dundas dairying is the rule. In Lancaster Township, Glengarry County, flax-growing is being developed on the fine, sandy loams there. The crop is well adapted and will probably persist as long as there is a market for the fibre.

7. *Silt, and Fine, Sandy Loams*

In one way the silt and fine, sandy loams are of special interest. Although they are only fair for general farming, perhaps none of the other types hold such possibilities for improvement. The area has been estimated at 174,000 acres, most of which is in a belt across southern Russell County,

extending into Carleton and Prescott to the west and east. A small area of similarly textured soil in Renfrew County west and south of Pembroke is included.

The level topography, freedom from stones, perviousness, good water-holding capacity and the ease of tillage of this type give it ideal properties from these important standpoints. However, lighter textured soils such as these present a peculiar problem in drainage. Water seldom lies on the surface so they are too often looked upon as having good drainage. The fact that it soaks in, rather than runs off, merely creates a waterlogged



FIGURE 6. Profile of Poorly Drained Silt Loam as seen near Russell Village.

condition of the subsoil and until this is overcome the fine physical properties just mentioned cannot be fully exploited. Deep ditches are necessary here since it is the subsoil rather than the surface drainage that is to be secured. Of course, drainage conditions are not perfectly uniform; bordering streams, in particular, there are bands with better drainage.

The profile development varies with texture and drainage conditions. The wettest patches have a faint horizonal development, as illustrated in Figure 6, while with better drainage a podsol profile develops making the surface layers gray, acid and low in organic matter. In all but exceptional sites, the subsoil is heavily mottled with rusty yellow and brown due to periodic waterlogging.

This type is characterized by low fertility levels. The more highly leached (greyer) soil needs lime. From a comparative standpoint, phosphate

levels are medium. Potash is deficient, this element and nitrogen constituting the limiting factors to plant growth. It will be realized from this that barnyard manure is well suited to the fertility needs of this land, so it is of special importance here to keep as much livestock as possible and to handle the manure with a minimum of loss. The application of commercial fertilizer will be feasible only where good drainage has been provided. If it is to be put on grain or clover seedings a complete fertilizer containing plenty of potash is advised.

This soil is well adapted to potatoes, being the best for this purpose in Eastern Ontario. In Carleton County there is a considerable acreage used for potatoes that go to the Ottawa market. Barley is another cash crop that might be better developed on this type of land.

9. *Well-drained, Gravelly Loam*

This is the gravelly loam commonly found in narrow strands or ridges. Geologically, these are either abandoned sea beaches or smoothed-off eskers. It is not an extensive type. The largest area, on an esker, runs from a point just southeast of Ottawa to one mile east of Kemptville. All the other areas large enough to be shown on a small scale map are in Carleton County. The total area is calculated to be about 41,000 acres.

This is early soil, the well-drained gravels warming up rapidly in the spring. For the same reasons it is somewhat drouthy, so early season crops are the logical choice. A fairly good idea of the profile can be obtained from Figure (7).

It has been found impossible to generalize as to the chemical properties because the samples tested gave such variable results. The frequency of abnormally high tests reflects special fertilization, and there are two apparent explanations for this. South of Ottawa a strip of this soil is utilized in growing early potatoes, sweet corn, tomatoes and such crops on which extra manure and commercial fertilizer is used. In the western part of Carleton County this type exists as low ridges in association with shallow soil. The farmers here put nearly all the manure made from the whole farms onto the strips of deep soil, thus bolstering the levels of fertility. It is therefore suggested that soil tests always be obtained and treatments based on their results.

10. *Sands*

The poor sandy soils of Eastern Ontario occupy about 12.5% of the total area. This is 688 square miles or 440,000 acres, scattered over Grenville, Dundas, Prescott, Russell, Carleton and Renfrew Counties as shown on the map.

The profile development in these sands varies according to the drainage conditions. Both the normal and the ground-water podsol are present. In well-drained sites only a shallow gray layer of one or two inches develops and the brown "B" layer beneath is also faintly developed. Where the water table is only 2 to 4 feet from the surface, a gray layer of 4 to 6 inches is common and an indurated hardpan several inches thick develops. Of the two types just described the normal podsol is better than the half-bog type but even at best it is marginal. Only a small percentage is cultivated,

some is utilized as pasture while most of it lies abandoned. Here and there some reforestation has been done, pines having been planted. Where farming is attempted, alfalfa will not grow because of acidity, oats get "greyspeck", a disease attributed to deficiency of manganese; corn is



FIGURE 7. Two Profiles of Gravelly Soil.

spindly, exhibiting the discolourations of foliage due to either nitrogen, phosphorus or potash deficiency, and even though it is reputed to be good potato land the growing of this crop in a commercial way is not generally successful.

11. *Burnt-off Peat*

In Prescott, Dundas and other counties there are small tracts of clay soil which have been reclaimed by burning off a shallow deposit of peat. This land may be recognized by the treeless landscape, the lack of a normal surface horizon, and sometimes by the presence of ashes in the surface along fence rows or in other uncultivated locations. The subsoil is a gray mottled clay throughout.

The dominant characteristics of this type are poor drainage and a poor structure in the plowed layer. It takes years for raw clay subsoil to get the admixture of humus which is necessary for good structure. Plowing



FIGURE 8. Peat on a Bed of Clay, partly Burnt Off. Taken near Cannamore.

in a certain amount of peat would be helpful but it is not always possible to burn off the peat so as to leave only a few inches. Fertility varies widely; after burning, the ashes provide potash and some phosphorus. Later, when this source of mineral salts has been exhausted, there may be deficiencies in this as there is in adjacent clay loam soils.

Timothy, alsike and oats are practically the only crops grown.

12. *Peat*

Peat and muck are seldom used as soil in Eastern Ontario. Near Ottawa some muck is being used to produce truck crops, but this is the only big enterprise of the sort noted in the whole region. Small spots of peat or muck are frequently included in fields in association with other soils and so are cultivated along with the rest. Except in such cases it seems logical to leave it alone.

In a few places the peat is used for fuel, invariably in localities where good clay soils have been completely cleared of woods. Here the fuel peat substitutes for cordwood which is elsewhere quite abundant in Eastern Ontario.

13. *Undifferentiated, Rock-knob and Shallow Soil*

In the southern part of Leeds County where the Frontenac Axis extends across the St. Lawrence Valley, in Carleton southeast of Arnprior, north of Renfrew and along the east side of Muskrat Lake there are belts of this shallow soil and rock-knob mixture. It also borders the entire area on the west. In the calculation of the total acreage we have arbitrarily included a strip along the western border so that there is a total of 416 square miles of this type, which is 7.5% of the total area.

The proportion of soil to rock outcrop varies quite widely from place to place. First there are those cases where the "land" was submerged under salt water. Here wave action denuded the rocks while clay was being deposited in the depressions. This condition is found in Leeds and Carleton Counties. Then there is the opposite condition where the till is unusually deep and fewer rock outcrops appear. Such is to be found near Westport in Leeds and south of the town of Renfrew. Of course, the most of it is between these two extremes in the proportion of rock outcrop present.

The profile of the soil on these rocks is that of a weakly-developed podsol, the grey A_2 horizon seldom being 2 inches deep. The till contains a predominance of acidic rocks except in several places in Renfrew County where it is affected by crystalline limestone.

The farms in operation on this type of land tend to be on the deeper soil areas or where there is clay between the bare knobs. The remainder is for forest rather than agricultural land. "Timber farms", as known in Scandinavia, have not yet been initiated in these woodlands. Perhaps it awaits a denser population with all that this implies.

PHYSICAL FACTORS

In order to show as clearly as possible the distribution and variation in the main physical and chemical characteristics of the soils in Eastern Ontario, these factors are now to be discussed singly with the aid of separate charts.

Topography

The outstanding fact about the relief of Eastern Ontario is that very little of it is too steep for cultivation. Except on the rock knobs, the only non-arable slopes are along the stream courses and the stream-cut bluffs of the abandoned channels of the Ottawa River. Rolling topography occurs in the deeper till areas, as illustrated in our account of the physiography (2, see block-diagram on page 426). The clay and sand plains are fairly level with certain exceptions. In the floor of the abandoned stream channels east of Ottawa there are several occurrences of humpy relief that was carved by stream erosion. Similar topography is common in Horton Township northeast of Renfrew.

Damage due to soil erosion is practically all confined to rolling, stony loams. Sheet washing on the steeper slopes occasionally exposes the grey subsoil but the amount of land affected is not great.

Depth

The depth to bedrock is a very important attribute. Figure 9 shows the distribution of deep and shallow soil and the area having only a few feet to the rock. The deeper tills bury the rock to a depth of 50 feet or more while the deepest marine clays are over 200 feet in depth. The



FIGURE 9. Generalized Map of Depth to Bedrock in Eastern Ontario.

shallow soils have generally less than a foot of soil. In the last division the bedrock is near enough to restrict drainage and is very often so close to the surface that ledges interfere with the installation of deep ditches.

It can be seen from the chart that nearly one-fourth of the total area is shallow over bedrock. If we add to this the rock-knob and shallow soil association, plus the moderately shallow, over one-third of the area would be represented. That is to say that about one-third of these eastern counties have poor soil due to shallowness.

Drainage

The topography, nearness to bedrock or impervious strata, and the texture of the surface soil particularly, combine to govern the drainage status of a soil. Figure 10 shows an interesting picture of the distribution of good, mediocre and poor drainage. The larger peat bogs are also added. About 5% of the total area is occupied by peat bogs, 40% by poorly-drained land, another 10% by land with mediocre drainage and the remaining 45% by well-drained soil. About half of this well-drained soil is shallow and



FIGURE 10. Soil Drainage Status in Eastern Ontario.

another quarter is sandy, leaving only about 10% of the total area in which there are good, well-drained soils. However, the most productive soil of all is that with naturally poor drainage but in which good drainage has been provided by open ditches or tile drains.

In spite of the great amount of drainage work already done, the need for better drainage is the biggest single problem presented by Eastern Ontario soils. General recognition of this fact is particularly important because community effort is so often essential in installing the main drains.

Stoniness

Figure 11 shows the stoniness of the soil and the picture presented is one of sharp contrasts. Over half of the total area is practically stoneless while the other extreme is well represented. Some of the stoniest land in the province exists in localities shown on the map. In these townships the stone piles and stone fences stand as a testimony of much hard work, and many sites are so bouldery that they are still uncleared, being in rough pasture or still in woods.



FIGURE 11. Stoniness is Indicated by the Density of Dots.

Texture

The texture of the surface soil is shown fairly well in Figure 2 so no separate map will be given. The heaviest soil is the clay in Eastern Carleton, Russell and Prescott. Next comes the clay west of Ottawa extending into Renfrew County, and similar soil in Leeds and on Wolfe Island. In Dundas County the clay loam is a little lighter and in the Carp Valley a little more loamy still. The loams consist of stony loams on glacial till and some of water-laid origin situated in the flats between drumlins in North Gower and Osgoode Townships and in other places. The fine sands and silts are well-delineated on the map, although those in

Lancaster Township in southeastern Glengarry should be included. The sands vary in coarseness, with the coarsest being associated with the jack pines in Renfrew County, particularly around Petawawa.

CHEMICAL FACTORS

The chemical characteristics of the soils were based on the results of soil tests on 464 samples collected during July and August 1939. The samples were of surface soil taken, with few exceptions, from hay or pasture



FIGURE 12. Soil Sample Locations.

fields. Care was exercised to avoid freshly-manured land, this being rather important because of the widespread practice of manuring clover fields. The sample locations are shown in Figure 12.

The methods of testing were the same as those used for South-Central Ontario (2) excepting that the acidity was measured by means of a Coleman pH-meter with a glass electrode. Supplementary analysis of organic matter and soluble phosphorus will be described in due course. These were made on composite samples of each type.

Reaction (pH)

Figure 13 serves to summarize the pH measurements. A little less than 50% of the soil is acid, the rest being in the near-neutral range. Some of the rolling, stony loam in Glengarry is alkaline with free carbonates being present in the surface soil due to erosion of the topsoil or the turning up of subsoil with the plow where the profile is very shallow, but the amount of calcareous soil is small. If we consider only the better land, eliminating

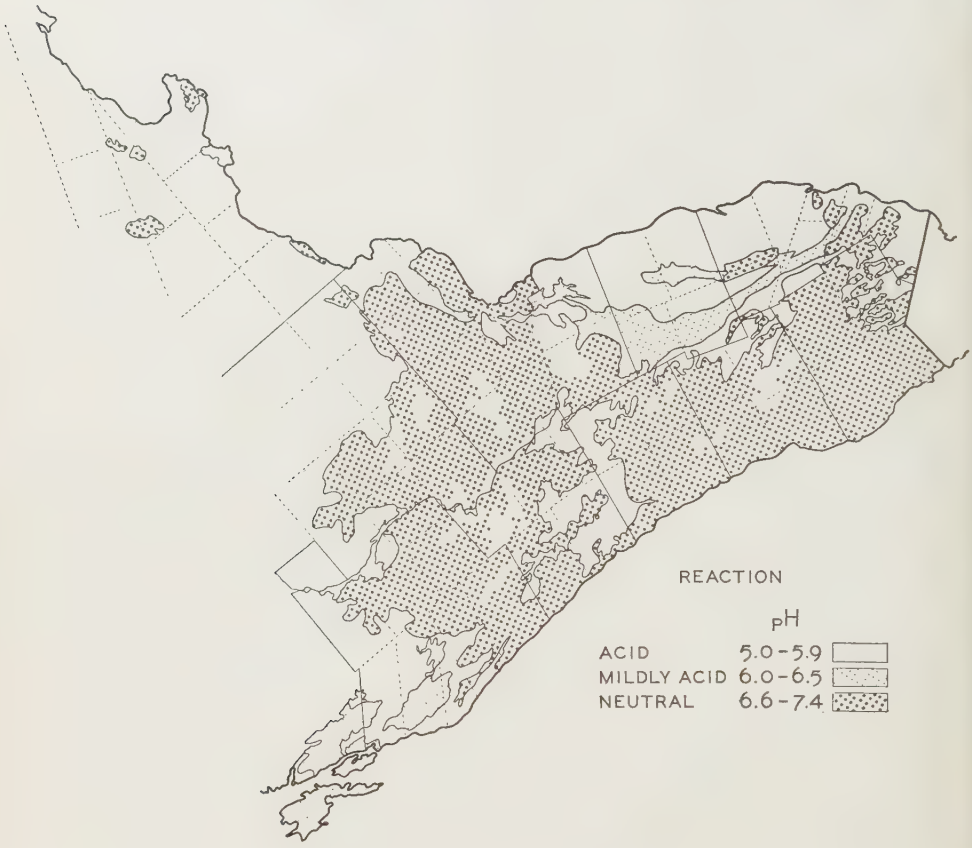


FIGURE 13. Soil Acidity in Eastern Ontario.

the shallow and the sandy for the occasion, the amount of acid and circumneutral soil is just about equal.

The most acid soil is the peat in the sphagnum bogs. The most acid of the cultivated soils is the grey-surfaced clay of Russell and Prescott Counties, where the pH varies from 4.5 to 6.0 in cultivated fields. The shaly till soils are nearly as acid. The sands are next with the podsol clay of Renfrew County and adjacent townships close behind. In Leeds County and Wolfe Island the most acid clay knolls have a pH of about 5.5, while most of it lies between 5.5 and 6.5. The reaction of the fine sandy and silt loams of Russell, Carleton, Prescott and Renfrew varies widely. Both light and dark-surfaced soils are included in this division, so the reaction varies from neutral to strongly acid.

Available Calcium

Along with the pH determinations, Spurway tests for soluble calcium and magnesium were made to appraise the need for lime. On this basis three divisions were made and Figure 14 drawn accordingly. The lowest-calcium soils are in need of lime. Oddly enough, the lightest sand and the heaviest clay soils are found in this category. The sands are, for the most part, not worth liming but the clay soil should certainly be limed. The middle class is in doubtful need, that is it may or may not give good response

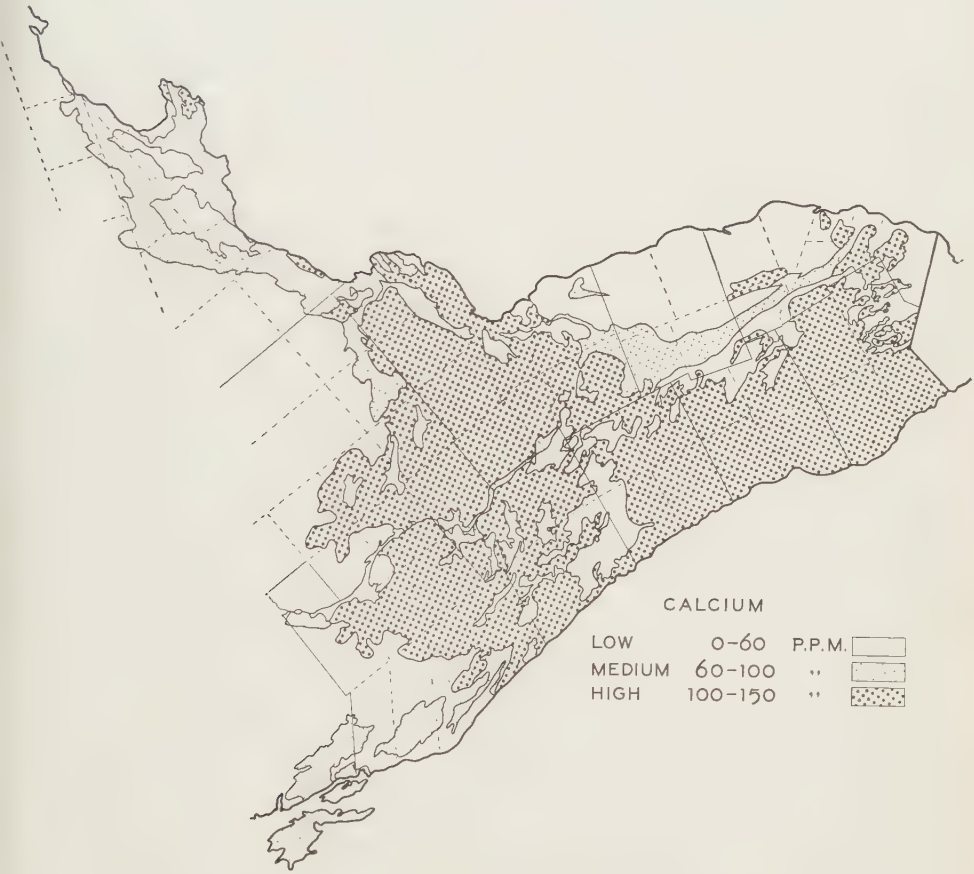


FIGURE 14. Available Lime in Eastern Ontario Soils.

to liming. There is a definite need for some field tests on this point. The third division is one in which there is not a lack of lime.

Soluble magnesium levels varied considerably but none of the soils were low enough to indicate a deficiency. On this account we have not prepared a chart for soluble magnesium.

Available Phosphorus

Phosphorus tests were made according to the Spurway method and also by the Lamoth-Truog field test in which a $KHSO_4$ solution at pH 2.0

was substituted for the buffered sulphuric acid solution. By using these two tests both the immediately available and the reserve are assessed. The map (Figure 15) is based on the stronger acid extraction because the reserve of phosphorus in easily soluble form is our principal concern in a basic soil description. The Spurway test was particularly useful in spotting samples from fields that had been fertilized recently and which therefore were rejected as abnormal and not used in characterizing the soil type.

The amount of available phosphorus in the soils under discussion varies widely in the manner shown by the map. The poorest have no more than



FIGURE 15. Relative Amounts of Available Phosphorus in Surface Soils.

15% of the amount present in the best supplied. The highest in this element are dark-surfaced clay loam and loam. Being poorly drained and having developed under elm and ash, leaching was very ineffective. The rolling limestone soils are next best supplied, particularly in Glengarry, Stormont and Dundas where the Trenton limestone predominates. The counterpart in Carleton and Grenville, which is influenced by the Beekmantown dolomite, is distinctly lower according to the tests. The shaly till soils are quite deficient in phosphorus, like similar soils in Halton and Peel Counties. In the acid clay soils there is an analogous variation due to

geological material, that on the pink and gray clay being low while the gray clays of Leeds, Lanark and Renfrew are relatively high in this element. The acid silt and fine sandy loams occupy a middle position on this basis while the sands, being well leached, contain the least available phosphorus.

Potash

It is an established principle that available potash is correlated to soil texture, sands being low and clays high in comparison. Beyond that there may be variation due to geological material especially in the heavier



FIGURE 16. Available Potash Levels Normally Present in Eastern Ontario Soils.

soils. Eastern Ontario soils bear this out as illustrated by Figure 16. The clay and clay loam soils make up the highest category and the sands the lowest. The shaly soils are better supplied than the limestone soils. The fine sandy loam and also the silt loam contain not much more potash than the sands, and because they are better soils, here is the best chance of utilizing potash fertilizer to advantage. Also, potash, can be used to advantage on most of the loams.

Organic Matter

The humus content of a soil is an indirect measure of its ability to supply nitrogen to the crop. Tests for nitrates or ammonia can be made

but the amount in the soil solution fluctuates with the season, weather conditions and the uptake by plant roots, so that they are of little use in describing a soil type. Not only is organic matter a source of nitrogen but it is also a source of trace elements such as boron, not to mention its effects on physical properties.

The humus content was determined only on composite samples of the various types, the wet combustion method of Walkley and Black being used (8). It may be said that the figures obtained confirm what one would expect, judging from the appearance of the soils. The neutral clay loam is best supplied, containing about 3.5%, while the sandy soils have only about 1.5%. The acid clay of Russell County and vicinity have nearly 3% while the other acid clays are lower. The limestone till soils also contain nearly 3% while the fine, sandy loams have 1% elss.

On the basis of this information it is hardly possible to predict that certain soils will be nitrogen deficient, but it indicates the danger zones, namely, the clay loams of Renfrew, Lanark and Leeds and the fine sands and silts of Carleton, Russell and Prescott. This latter type is most apt to lack nitrogen, as alfalfa does not thrive on it as it does on the clay soils mentioned. Of course, there is the appearance of the crop to guide one in this matter.

Fertilizers

The foregoing charts, based on tests for "available" nutrients, show the relative amounts of each normally found in the various soils. There are variations in the different samples of the same soil type, nevertheless the figures group themselves around a modal value. In other words the soil type means something in terms of phosphorus, potash and lime; and while recognizing that specially treated fields are included we feel that it would be amiss not to propose general fertilizer programmes for specific soils. The owners know the fields that have been specially fertilized and can proceed accordingly. Therefore, a map of fertilizer zones (Figure 17) has been prepared, taking into consideration lime, phosphorus and potash.

The first division consists of shallow, stony, sandy or swampy soil on which it is considered unwise to apply fertilizer. There are occasionally small patches of good soil throughout this No. 1 area that would repay the cost of special fertilization, in which case the type may be identified or soil tests can be obtained.

The second division embraces the acid clays that need phosphate, lime and organic matter. Lime is particularly deficient east of Ottawa. The third division has much the same fertilizer requirements but lime is not needed. Also, potash is lower and phosphate higher than in the acid clays, so a fertilizer like an 0–16–6 is indicated if the land has not been well kept. For the No. 4 division, which lacks potash and phosphorus, a fertilizer like a 2–16–10 is recommended where nitrogen is needed, and 0–16–6 where it is not. Nitrogen is apt to be low in the silt and fine sandy loams, which may also benefit by lime, particularly the better drained type with grey surface soil.

CROP RATING

The outstanding crop adaptations have been noted already when discussing the various types. In addition to that, each type has been rated as to its ability in the production of eight staple crops as shown in the accompanying table (Figure 18). It is recognized that crop response is governed by climate as well as soil, but the similarity of the climate over Eastern Ontario makes a comparative rating of this sort basically sound within this area. It will be seen that the land types are graded from

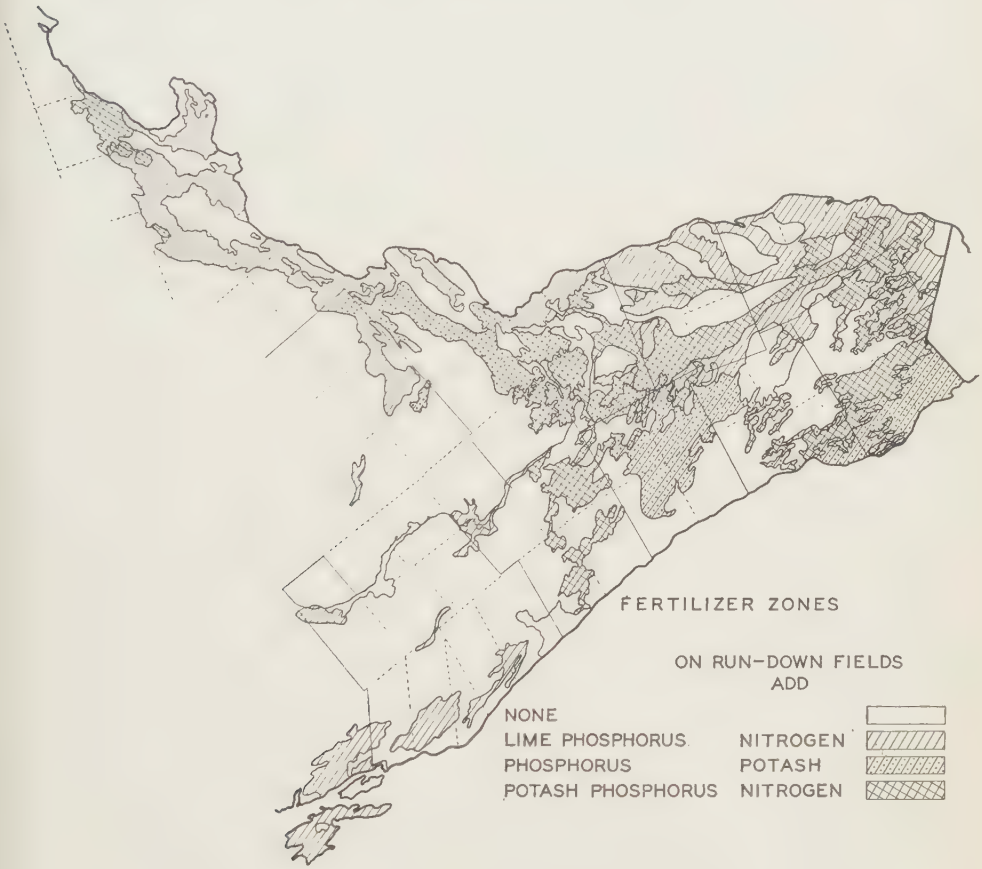


FIGURE 17. Fertilizer Zones in Eastern Ontario.

1 to 10 according to their suitability for each crop. This rating is based on the opinion of the authors only since data on average yields are not available.

DISCUSSION

About half of Eastern Ontario is occupied by poor soil, one-half of which is shallow, drouthy soil, one-quarter poor, sandy soil and the rest swampy, rocky or peat bog. The shallow soil presents a peculiar problem. Here there has been some farm abandonment with consequent increase in size of farms. Since these farms are used mainly for pasture, larger farms are necessary for a family to make a satisfactory living. The problem is, therefore, one of grouping undersized farms without delay so as to forestall

FIGURE 18. CROP RATINGS

Land type	Alfalfa	Red clover	Timothy	Oats	Barley	Fodder corn	Potatoes	Alsike
No. 6	8	10	9	10	10	8	3	8
No. 5(*a*)	9	10	8	8	9	7	3	10
No. 5(*b*)	1	10	10	6	6	6	2	8
No. 3	10	8	7	8	8	10	8	6
No. 9	1	1	2	1	3	3	6	1
No. 7	2	5	5	5	5	5	10	6
No. 4	10	7	5	6	6	8	8	6
No. 2	3	3	5	3	3	3	3	5
No. 1	4	2	3	2	3	3	2	2
No. 10	5	7	9	5	4	0	2	8
No. 8	0	1	2	1	2	0	3	3
No. 11	6	7	4	5	7	7	8	4

the slow process of failure and abandonment which entails so much disappointment and demoralization. Perhaps some tracts of this land, such as parts of Marlborough and Montague Townships, might better be depopulated if the cost of schools, roads, churches and health services is more than the farms within the tract can support. There are also tracts of sandy soil where depopulation and resettlement of these families elsewhere might be advisable.

In connection with the poor soils, it may be stressed that although soil tests tell whether a soil is low in nutrients they do not tell whether it is a good "base" for commercial fertilizer. At present it is not feasible to fertilize the shallow, stony, sandy or wet soils.

The other half of Eastern Ontario has good soil, that is 35% is high grade land and 15% fair. The heavy clay of Russell and Prescott, together with the fine sandy loams in the same counties and some of the shallower limestone till soil, constitute the 15% classed as fair land. The clay loams and deep stony loams make up the first-class land. Any of these soils are worthy of considerable expense and labour for their improvement.

The best possibility of gain by means of drainage work is with the dark-surfaced clay loams and loams which have the highest latent fertility. However, these have not been neglected so much as the silt and fine, sandy loams of Carleton, Russell and Prescott, which require deep ditches to obtain subsoil drainage.

The fertility needs are discussed in the paragraphs on fertilizers and lime requirements. The outstanding needs are: lime on the grey clays east of Ottawa and on the silt or fine, sandy loams in the same counties; phosphate on the clay soils; phosphate and potash on the loams and fine,

sandy loams; nitrogen on the fine sandy loams and silt loams and sometimes on the "white" clay soils.

In addition to pasture, hay, oats or mixed grain and fodder corn, it is normally desirable for the Eastern Ontario farmer to have a supplementary cash crop. On the Renfrew County clay lands alsike seed and seed grain have succeeded because of the comparative scarcity of weeds. Some peas are also grown. On the clay land of Russell and Prescott red clover seed does well and malting barley can be grown. On the fine sandy loams in Carleton and Russell some potatoes for local markets are grown and some malting barley. It is suggested, however, that the best place for potato-growing is in the vicinity of Pembroke, since this section has a definite climatic advantage. In Lancaster Township on silt and fine sandy loams flax for fibre is being grown for a local mill and the crop is well adapted. With the exception of hops, for which there is a limited market, there do not appear to be any valuable crops suited to the sandy soils or to the other poorer types of soil.

It is notable that Winchester Township has the densest livestock population of any township in the province. Specifically, there is an average of 33 livestock units on every hundred acres. (1 "livestock unit" = 1 cow = 1 horse = 5 hogs = 7 sheep = 100 hens). The Carp Valley and some of the clay loams of Renfrew County carry less than 20 livestock units per hundred acres. This difference is at least not all due to the productive capacity of the soil and it is considered that some sections could carry more livestock advantageously.

SUMMARY

The soils of Eastern Ontario are younger than those of Central and Southwestern Ontario, hence leaching has proceeded for a shorter length of time. However, this is counterbalanced by a colder climate which results in more severe leaching here, especially up the Ottawa Valley where coniferous forests are found.

As a result of level topography, drainage is poor in about half of the area, constituting a major problem for the farmers of the region. On higher sites the most obnoxious characteristic is stoniness. Some of the best land was originally either poorly drained or stony. The poor land is made up of the shallow, sandy, wet and stony, or excessively stony soil and bog. On this basis there is more poor land than good, the areal ratio being about 60 to 40.

The chemical nature of the soils was studied through a collection of 464 samples taken from hay and pasture fields. After testing these samples it is possible to point out the soils with the most, least, and an intermediate amount of lime, phosphate or potash. Furthermore, an attempt was made to divide the area into zones with similar fertilizer and lime requirements. The need of experimental work in certain cases is also indicated and those soils considered unworthy of expensive treatment under present economic conditions are also mapped.

An added item of description is the table of numerical ratings for each type of land as to its ability to produce several staple crops. It is intended that more specific studies will be made on the adaptation of crops; that is one of the main reasons for making this survey of the soils.

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STUDIES ON SURFACE TAINT BUTTER[1]

VI. OTHER BACTERIAL SPECIES AS CAUSAL AGENTS. *FLAVOBACTERIUM MALOLORIS* (n. sp.).

H. Wolochow[2], H. R. Thornton[3], and E. G. Hood[4]

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INTRODUCTION

There is agreement that *Pseudomonas putrefaciens* is a cause of a flavour defect of butter which is known as surface taint in Canada (8), surface taint and putrid butter in the United States (1, 2) and rabbito in Australia (5).

Shutt (7) attributed to *Pseudomonas fluorescens* a defect of Canadian butter which he called "surface flavour". Presumably this is the same defect as is generally known as surface taint. Rice (6) regarded *Pseudomonas* as a cause of rabbito, while Derby and Hammer (2) found *Pseudomonas fluorescens* to give a defect in butter which resembled surface taint for 3 or 4 days but later changed into rancidity.

A number of workers report that other species of bacteria are capable of causing this defect but fail to name or describe them. It is, therefore, not out of place to present further data relative to the types of bacteria capable of causing surface taint in butter. A species capable of causing the defect and believed to be newly described will be discussed.

PSEUDOMONAS FLUORESCENS

Green-pigment-producing bacteria are so widely spread in Alberta well waters and butters that of the 2500 isolations in the present study several hundred were of this type. When grown in sterile skim milk at room temperature for about 2 days, these cultures produced an odour rather suggestive of surface taint. By the end of about 4 days the odour changed to a strong cowy or barny odour. At no time was the odour to be mistaken for the sweaty feet odour of *Ps. putrefaciens* in skim milk culture and the odour was not intensified, indeed it disappeared, when the culture was allowed to dry to the point of stickiness on the fingers. No difference was discernible between raw and heat-treated, aseptically-drawn milks as substrates for these organisms. Fatty acid, but not sweaty feet, odours were liberated by acidifying the residue obtained from the evaporation of $Ba(OH)_2$-retained steam distillates of skim milk cultures. Nine cultures chosen at random were identified as *Ps. fluorescens*.

A total of 20 experimental salted and unsalted churnings was made from raw and pasteurized cream which had been incubated at 10° C. to 15° C. overnight after inoculation with *Ps. fluorescens* (involving a total of 7 cultures). Some of the unsalted pasteurized-cream butters were graded surface taint, or questionable surface taint, 24 hours after churning.

[1] Joint contribution from the Division of Bacteriology and Dairy Research, Science Service, Department of Agriculture, Ottawa, and the Department of Dairying, University of Alberta, Edmonton. Contribution No. 148 (Journal Series), from the Division of Bacteriology and Dairy Research, Science Service, Department of Agriculture, Ottawa.

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Within a further 24 hours these butters were graded rancid (the butyric acid type of rancidity). All the butters without exception finally graded rancid, while salt had merely a delaying effect. With the exception noted above none of these butters graded surface taint. These results lack the clarity of similar trials with *Ps. putrefaciens* and, indeed, lack the definiteness inferred in this description.

The results point to the conclusion that odour production by *Ps. fluorescens* is a different chemical phenomenon from odour production by *Ps. putrefaciens*. Nevertheless, it would appear possible that for a very short period a commercial churning might be graded surface taint because of the influence of *Ps. fluorescens* but, no doubt, such a butter would quickly become rancid. Commercial surface taint butters frequently do later develop rancidity. This bears no necessary relation to the surface taint problem because of the widespread distribution of *Ps. fluorescens*, because rancidity is by no means confined to surface taint butter and because many samples of surface taint butter do not develop rancidity. In holding periods that varied up to 21 days, rancidity was not observed in any experimental butter made from pasteurized, sweet cream of high quality inoculated with surface taint bacteria.

Because of certain clear-cut features of commercial surface taint, such as its sudden and spectacular appearance in western Canadian butter, and because of the definiteness and clarity in experiments with *Ps. putrefaciens* and lack of clarity with *Ps. fluorescens*, it seems improbable that the latter organism is a major contributor to this defect.

A YELLOW BACTERIUM CAUSING SURFACE TAINT

Among the 2500 random bacterial isolations previously described there were 5 cultures of a yellow-pigmented organism. The skim milk cultures emitted an odour suggestive of sweaty feet, and the odour was intensified when a few drops of the cultures were allowed to dry to the point of stickiness on the fingers. Typical sweaty feet odour was recognized as being liberated by acidifying the residue obtained from the evaporation of $Ba(OH)_2$-retained steam-distillate of skim milk cultures. The odour was not produced in raw milk, at least detectably so. From inoculated high-temperature pasteurized cream all 5 cultures produced defective butter which graded surface taint. The defect did not appear on butter churned from inoculated raw cream. The odour defect in milk and usually in butter was very much milder than in the case of *Ps. putrefaciens*.

The 5 cultures were isolated from the water supply of one Alberta creamery. Isolations were made from the water of each of two wells supplying the creamery as well as from the creamery tank water.

It is believed that this organism is less important in commercial surface taint than is *Ps. putrefaciens* because:—

1. It has not hitherto been reported as a causal agent.
2. It was isolated so infrequently in these studies.
3. It usually produces a remarkably milder attack of the defect.

Description of the Organism

Morphology

The cells, when grown in milk, were rods, 0.3 microns to 0.7 microns by 1.1 microns to 2.9 microns, with rounded ends and occurred singly and in pairs. They were somewhat smaller when grown in nutrient broth. The gram reaction was never found to be other than negative and spore-formation was not observed. Motility was not demonstrated, either under the microscope or by means of semi-solid agar stabs, and a number of attempts to stain flagella were unsuccessful.

Chromogenesis

Growth was characterized by yellow to yellow-orange chromogenesis on all media tried. Diffusion of the yellow colouring matter into the medium was not observed and diffusion into the aqueous portion of water-suspensions of the organism did not take place. Neither chloroform nor di-ethyl ether extracted the colour from boiled or non-heat-treated, acidified water-suspensions of the organism. These water-suspensions were yellow at pH's of approximately 7 or below and mauve to pink at approximately pH 11.

Cultural Characteristics

Gelatin colonies were punctiform, translucent and liquefying, with smooth surfaces and entire and undulate edges. Gelatin in stab cultures liquefied with crateriform liquefaction changing through infundibuliform to completeness. The liquefied portion was unchanged in colour and there was a yellow sediment.

Agar surface colonies were circular, raised, smooth and glistening with entire edges and varied in diameter to over 1 cm. in 3 days at 21° C. They were yellow to yellow-orange by reflected light and brownish by transmitted light. The internal structure was amorphous. The sub-surface colonies were lens-shaped and appeared brownish by transmitted light. Agar slant growth was fairly abundant, translucent, glistening, butyrous and yellow to yellow-orange in colour.

Broth cultures exhibited moderate turbidity with a thin, membranous pellicle and scanty, flocculent sediment. In aged cultures a yellow ring was formed.

Growth on potato-dextrose-agar slants was filiform and not as deep a yellow as on agar slants. Growth on potato was raised, glistening, echinulate and butyrous and in the presence of excess moisture luxuriant growth covered the entire surface of the slant. The colour of the aged growth changed from deep yellow to dark orange. The growth was surrounded by a halo of lighter coloured potato tissue 1–2 mm. wide which in the presence of iodine gave a less intense purple colour than the remainder of the potato tissue.

Nitrogen

Indole was slowly produced and ammonia was regularly produced from proteins. That the organism is highly proteolytic in skim milk is

seen from Figure 1. The non-protein nitrogen (NPN) was determined by the Kjeldahl method applied to the fraction not precipitated by trichloracetic acid. Formol nitrogen, which includes ammonia and free

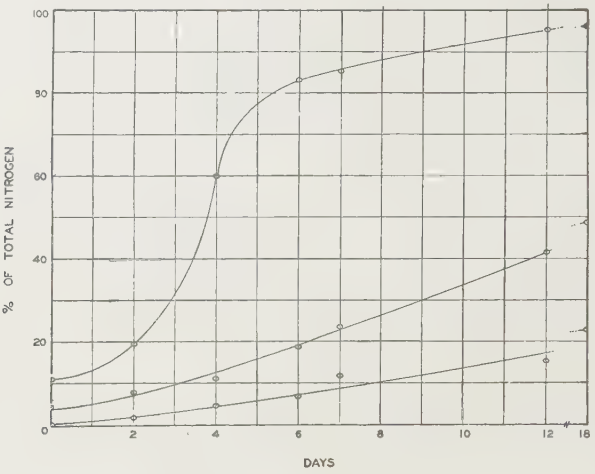


FIGURE 1. Nitrogen distribution in skim milk cultures. Upper curve—NPN, Middle curve—formol nitrogen, Lower curve—Ammonia.

amino nitrogen, was measured by the formol titration method and ammonia was determined by the aeration method of Van Slyke and Cullen.

Inorganic nitrogen in the form of $NH_4H_2PO_4$ was not available to the organism and methyl and ethyl amines (protamines) were not utilized when the technique of den Dooren de Jong (4) was followed.

Tests for nitrite in 1% nitrate broth cultures were uniformly negative. Cultures growing in broth containing 2 p.p.m. of potassium nitrite remained positive to the nitrite test. Nitrate determinations by the phenoldisulphonic acid method applied to 1% nitrate broth cultures gave no evidence of nitrate utilization.

Litmus Milk

In litmus milk cultures the pH remained unchanged as indicated by the colour of the litmus. Peptonization occurred with a reddish, transparent layer appearing at the surface in about 2 days at 21° C. This layer gradually extended down the tube until peptonization was complete. A yellowish-white pellicle was formed.

E_h

No strain of this organism reduced litmus in skim milk cultures. As illustrated in Figure 2 the reducing intensity of skim milk cultures is not great. It was also observed that these cultures were not highly poised, indicating that the reducing capacity is low. It may be that the milk and butter defect caused by this organism is related to these low reducing intensities and capacities.

pH Growth Limits

The lower pH limit of growth in buffered broth lay between 5.22 and 5.03, while the upper limit was between pH 9.65 and pH 10.1. In skim milk the upper pH limit of growth was between 9.35 and 10.75. After 3

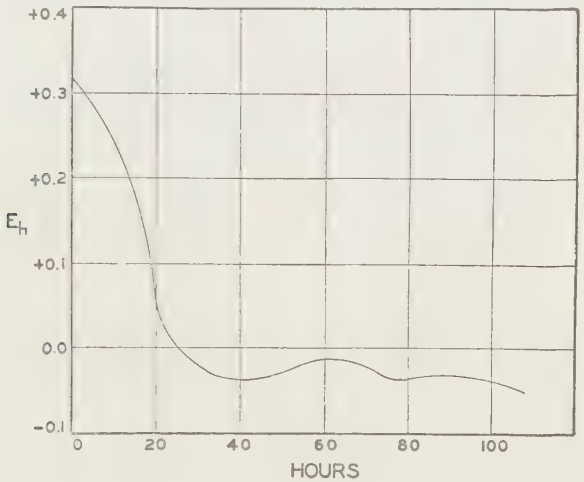


FIGURE 2. Eh changes in skim milk cultures.

days incubation in litmus milk having an initial pH of 6.64, the pH was unchanged (within 0.05 pH units), while at the end of 20 days the pH varied within the range 6.99 and 7.62 for the 5 strains.

NaCl Resistance

Growth occurred in broth containing 4.2%, but not 6.0%, NaCl. Growth occurred in skim milk containing 2.5%, but not 4.2%, NaCl. The salt concentrations were determined as in the Kohman method of butter analysis.

Aromatic Compounds

The organisms did not grow in the medium of Gray and Thornton (3) when phenol or meta-cresol was the sole source of carbon.

Carbohydrates

There was no definite utilization of glucose, sucrose, lactose or maltose by any strain as measured by the colour changes of brom thymol blue in broth cultures containing these carbohydrates. The electrometrically-measured pH changes of a representative strain in 1% sugar broths are shown graphically in Figure 3. Since the quinhydrone electrode was used the more alkaline values may be only approximate. There is no indication that lactose was utilized. If acid was produced from glucose, sucrose or maltose, neutralization by protein degradation products may have taken place.

The starch in starch broths was hydrolysed, even to completion, by all strains without change in colourimetrically-measured pH and the starch broth cultures reduced the copper in Benedict's solution. Cellulose

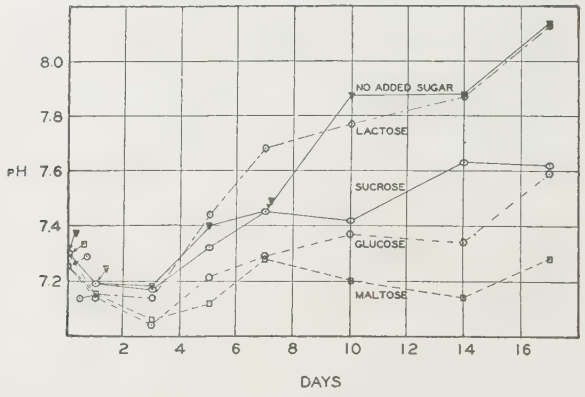


FIGURE 3. pH changes in 1% carbohydrate broth cultures.

utilization was not observed and acetyl-methyl-carbinol was not produced from glucose.

Volatile Acids

Volatile acids were produced in skim milk. The total acidity (average of 2 determinations) was found to be 68.9 ml. of 0.1 N. acid per litre of skim milk culture when the technique previously described (9) was followed. This is very similar to the total volatile acid production in skim milk cultures of *Ps. putrefaciens*.

Oxygen

The organism is an aerobe but grows in shake cultures to approximately 3 mm. below the surface of the medium.

Gas

Gas production was not observed in solid media. As measured in the Van Slyke volumetric CO_2 apparatus, small amounts of CO_2 (less than 7% by volume) were demonstrated in 5-day cultures in nutrient, lactose, maltose, sucrose and glucose broths. The proteins were, presumably, the source of the gas.

Hydrogen Sulphide

Shortly after isolation of the organism tests for hydrogen sulphide in nutrient broth cultures varied. Some negative strains later reacted positively.

Temperature

All strains grew on agar slants at 2° C. and 32° C. while 1 strain failed to grow at 37° C. Growth on agar slopes was faster at 21° C. than at 25° C.

No strain survived 57.2° C. (135° F.) for 5 minutes, when the technique previously described (10) was followed. Two strains were subjected to the following temperature-time combinations and failed to survive:—

60.0° C. (140° F.) for 5 minutes
62.8° C. (145° F.) for 1 minute
65.6° C. (150° F.) for $\frac{1}{2}$ minute

Taxonomy

The organism belongs in the genus *Flavobacterium* as described in the fifth Edition of Bergey's Manual of Determinative Bacteriology. The Chairman of the Board of Editor-Trustees of this Manual informs us that this genus is currently undergoing revision.

It is believed that this organism is a new species. The authors are aware of the objections to undue haste in naming new species but they also recognize the confusion that arises from undesignated descriptions. The tentative name of *Flavobacterium maloloris* (L. *malus* bad and *olor* odour) is, therefore, suggested.

Other Strains

Two cultures of yellow gram negative rods were supplied through the kindness of Dr. B. W. Hammer, Ames, Iowa, who informed the authors that the organisms were encountered infrequently in the Iowa studies of putrid butter. These cultures are identical to, or at least variants of *Flavobacterium maloloris*.

OTHER SPECIES

In the present studies no species encountered, other than those discussed herein, was suspected of surface taint producing ability.

DISCUSSION

In extensive studies of this problem in Canada, the United States and Australia *Pseudomonas putrefaciens*, *Pseudomonas fluorescens* and *Favobacterium maloloris* (n. sp.) are the only named or described organisms to which has been attributed the ability of producing this butter defect. In these various investigations not only have the methods of isolation varied but so have the criteria of defect production. If similar capabilities are possessed by other species of bacteria, it would appear that such species are either rare or difficult to isolate.

SUMMARY

Pseudomonas fluorescens is widely spread in Alberta creamery butters and waters but the results of experiments designed to establish its relation to surface taint are indefinite. They suggest the possibility of this organsim causing a defect of pasteurized-cream butter, presumably merely incipient rancidity, which is chemically different from surface taint but for a temporary period organoleptically indistinguishable from it. Ultimately all the experimental butters containing inoculations from pure cultures of *Ps. fluorescens* became rancid.

A yellow-pigmented bacterium, believed to be a new species, was isolated from the water supplies of one Alberta creamery. It produced a mild but typical sweaty feet odour in litmus milk and mild surface taint in butter churned from inoculated, high-temperature pasteurized cream. It is believed to be less important than *Ps. putrefaciens* in commercial surface taint. A description of the organism is given and the tentative name *Flavobacterium maloloris* is suggested.

No other species was suspected of surface taint producing ability in 2500 random isolations from normal and abnormal butters and creamery well waters.

ACKNOWLEDGMENTS

The authors wish to express appreciation to Mr. W. J. Beckett, Dairy Produce Grader-in-Charge, Edmonton, and his staff for grading numerous experimental butters; to Graders-in-Charge at various Western Canadian points for sending samples of defective butters; to the Dairy Commissioner of Alberta and his staff and the buttermakers of the province for interest and co-operation at all times; to the Department of Animal Husbandry, University of Alberta; and the dairy plants of Edmonton for many donations of cream.

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8. I. Odour production by *Pseudomonas putrefaciens*. Sci. Agr. 22 : 277-286. 1942.

9. II. An odourous compound in skim milk cultures of *Pseudomonas putrefaciens*. Sci. Agr. 22 : 347-355. 1942.

10. III. Some further characteristics of *Pseudomonas putrefaciens*. Sci. Agr. 22 : 438-447. 1942.

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12. V. The growth of *Pseudomonas putrefaciens* in butter. Sci. Agr. 22 : 552-560. 1942.

13. VI. Other bacterial species as causal agents. *Flavobacterium maloloris* (n. sp.). Sci. Agr. 22 : 637-644. 1942.

BOOK REVIEW

"Soybeans"—Gold from the Soil. By Edward Jerome Dies. Publishers: The Macmillan Company, Toronto. ($2.00).

The author presents a brief but complete and colourful story of the soybean. Brought into a single volume for the first time is the historical record of this versatile plant (beginning with the first written record which dates back to 2838 B.C.), its shift to the western world, the discovery of its magic qualities, the breeding of adapted varieties, planting, harvesting, and conversion into edible and industrial products.

This book cannot fail to hold the interest of the general reader. To the Canadian farmer the story of the rapid rise of the soybean, in the United States, to a position of importance in a few years will undoubtedly be regarded as one of the most striking developments in American agriculture. Of special interest to teachers, students, research workers and industrialists are the charts and tables dealing with production and consumption, as well as a chronology and a comprehensive bibliography.

T. M. S.